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THE MIDDLE ORDOVICIAN OF THE OSLO REGION, NORWAY

8. Brachiopods of the Suborder Strophomenida.

By
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Abstract. 79 Strophomenid brachiopods are described from the Middle Ordovician of the Oslo Region in Norway. They belong to 27 different genera and subgenera. 46 species or subspecies and 6 genera or subgenera are new. The structure of the valves is studied by serial sectioning and the results discussed. Fairly complete ontogenetic series of three species are described. The Middle Ordovician brachiopod fauna is rather different in the areas within the Oslo Region. In the Oslo—Asker and Ringerike districts the fauna is of a British—Irish type, and in the Langesund—Gjerpen, Hadeland and Mjøsa districts it shows Baltic affinities. In the Ringsaker district there are some species of American type.

PREFACE

The present paper is one of several being published by different authors on the Middle Ordovician of the Oslo Region. This team work was initiated and is led by Professor L. Størmer (Palaeontological Institute, Oslo).

The Strophomenids of the Oslo Region were described by Holtedahl (1916). This paper, which, to a certain degree has been neglected by later authors, is of very high class to have been written so early — in fact it was the first modern paper on the Strophomenids. HOLTEDAHL discovered the simple cardinal process in the early Plectambonitids, and also noticed that the convexity is an unstable feature, even within one species. He used the internal features (cardinal processes, teeth and muscle impressions) as the base for the classification, and pointed out that the division of the Strophomenids into Rafinesquinidae and Orthotetidae was completely artificial, and that the natural groups were the Plectambonitids and the Strophomenids. Later these ideas were further developed by JONES (1928), KOZLOWSKI (1929) and ÖPIK (1930, 1933, 1934).

Before 1916, there are no papers of palaeontological value on the Strophomenids of this region. It is worth mentioning that both KJERULF (1864) and BRØGGER (1887) briefly described *Kiaeromena kjerulfi* (HOLTEDAHL) and were aware of its value as a guide fossil, even if they did not give it a name.

KIÆR (1926) described a new species, *Leptaena minuta*, and JONES (1928) gave some information on the Norwegian Sowerbyellinids.

Due to the considerable collecting which has taken place during the later years, the present material is much more extensive than that available to HOLTEDAHL, and the number of species is therefore much larger in this paper.

The author wishes to express his most sincere gratitude to Professor L. Størmer for all help and advice, and to Professor Alwyn Williams (Belfast) for inspiring discussions. The author is also indebted to Dr. G. Henningsmoen and State Geologist S. Skjeseth for information on stratigraphy and collected material from the districts covered by them. Valuable information on foreign areas has been supplied by Mr. W. Dean (Cambridge), Mr. R. Cave (Cambridge), and Dr. V. Jaanusson (Uppsala), for which the author would like to thank them.

Material for comparison has been supplied by Professor O. Holtedahl, Professor E. Stensiö (Riksmuseet, Stockholm), Professor W. King (Sedgwick Museum, Cambridge), and Professor C. T. Stubblefield (Geological Survey and Museum, London), to whom I am deeply indebted.

The author also wishes to thank Miss L. Monsen for assistance with the preparation of the fossils and mounting of plates, Miss B.

Mauritz for photographing the specimens, Miss R. Gulliksen and Miss I. Lowzow for drawing the figures and diagrams, and Mrs. A-C. Brenna for revising and typing the manuscript.

Material and methods.

The present material of Middle Ordovician brachiopods from the Oslo Region is mostly preserved in shale, marls and limestone. Comparatively few specimens come from siltstones. Shale material usually is suitable for studying the internal structures. The specimens are either found as natural casts, or the shell substance can easily be dissolved in dilute hydrochloric acid to form casts. This procedure has been used extensively on the present material, especially with specimens preserved in shale, but also with those from marls and marly limestones. The latter specimens were usually very brittle when all carbonates had been dissolved, and they were therefore strengthened by spraying the specimens with celluloid or plexiglass (methylmetacrylate) dissolved in acetone. Usually, six to eight sprayings were enough, even with very brittle specimens.

In some species, where the interior could not be studied by dissolving the valves, it was necessary to make serial sections in order to reconstruct the interior. Serial sectioning was also used when studying the histological structure of the valves of some species. All serial sections, as well as most of the ordinary thin sections were made by the dry peel method. The procedure was as follows: The specimen was ground with fine carborundum powder until the desired surface was obtained. It was then etched for a few seconds with dilute hydrochloric acid, after which it was dried. The dry surface was pressed against a small piece of celluloid moistned with a few drops of acetone, until the acetone evaporated. When the specimen was freed from the celluloid, the latter showed an impression of the structure of the specimen. The celluloid casts had to be mounted on an ordinary object glass as soon as possible in order to prevent the celluloid from curling. When preparing a serial section, the grinding of the etched surface was continued until a new surface was reached, and then the etching was repeated. In long serial sections, it is necessary to protect the sides of the specimen against corrosion. This was done by giving the specimen a thin coating of wax or plexiglass.

The quality of the peel, compared to ordinary thin sections, was amazingly high. In well preserved specimens, they could be magnified up to 200x, and, in most cases, they show the histological details just as clearly as the thin sections. In order to verify this, the last surface of some of the serial sections were made into ordinary thin sections. For studies in polarized light, the thin sections are of course indispensable.

For this paper, about 25 serial sections were made, and about 450 additional dry peels and 35 ordinary thin sections.

A number of photomicrographs were made from dry peels, and no special measures were needed in order to obtain good pictures. Both thin sections and peels were photographed with the same light and optics (pl. 13, figs. 1, 3, 5).

During the preparation of the plates, it became evident that it is difficult to compare casts and positive specimens. Some features can be seen more plainly in the casts, while others only are clearly visible in the positives, as for instance the cardinal processes. Dr. Jaanusson of Uppsala has also kindly called my attention to the fact that scientists working exclusively with positive material (United States and the Baltic Region) generally have great difficulty in comparing their material with material which only is represented by casts. Authors working with cast material generally have experience both with casts and positives, and they do not so often have these difficulties.

The figures in this paper have, as far as possible, been made from positives. In some specimens, however, this was impossible, either because the original specimens (casts) were too brittle, or because the shape of the specimens made it difficult (the *Leptaena* species, with the angle between the fringe and the disc less than 90°).

Several casting substances were tried. Latex emulsion proved to be the most suitable, and, when carefully applied, gave casts showing all details, even those from deep cavities. Furthermore, they are elastic, can be handled easily, and adhering rock substance can be removed simply by washing the latex cast with soap and water.

Good photographs were not obtained from casts made by latex emulsion only, as they were semitranslucent and of a brownish-yellow colour. A large number of dyes were tried by the author, assisted by Miss L. Monsen and Miss B. Mauritz, in order to find a substance, which, added to the latex, would give an opaque surface, and a colour which gave good photographs. Different types of photographic negative material usually gave different results with different colours.

AGFA orthocromatic plates were used for the photographs in this paper, and the casts were made from latex emulsion with 10—20% pale blue commercial latex paint. These casts were of a very pale bluish-green colour. The addition of the latex paint did not affect the casting properties of the pure latex.

Besides the material from the Middle Ordovician of the Oslo Region, some specimens from other regions are introduced for comparison. Most of them belong to Paleontologisk Museum, Oslo. The lectotype of *Leptaena rugosa* and the specimen of *Strophonella euglypha* figured (pl. 12 fig. 7) belong to Naturhistoriska Riksmuseet, Paleozoologiska Avdelingen, Stockholm, Sweden.

General part.

THE SHELL STRUCTURE

The shell structure of the Strophomenids has been studied by Carpenter (in Davidson 1856), Kozlowski (1929), Öpik (1930, 1933, 1934), Williams (1953, 1953a), and a number of other authors.

The Strophomenid valve consists of two layers, the primary, external one, secreted by the edge of the mantle, and the secondary, inner one, secreted by the whole mantle. The secondary layer is, in most cases, much thicker than the primary one in adult specimens. The external sculpture is reflected on the inside of the external layer, as vascular or ciliar grooves. Later this sculpture is obliterated by the deposition of secondary tissue. The secondary tissue shows impressions of muscles and vascula, and specimens lacking the secondary layer are often devoid of these important diagnostic features. Young specimens, in which these features are not completely developed, may often show the diagnostic features of different species or even genus (cf. Öpik 1930, p. 32). The two layers are generally distinctly defined, except in a few species, as for instance *Ptychoglyptus valdari* (cf. p. 60).

The external layer is sculptured on both sides. It is generally very thin, and only grows laterally and not in thickness. The inner secondary layer increases in thickness as the animal grows older, and is therefore much thicker in gerontic specimens than in young ones.

In some species the inner layer is only slightly developed if deposited at all, and in others the majority of the adults are very thick-shelled. It is obvious that the ecological features, such as the temperature and the amount of calcium carbonate dissolved in the sea-water, will have affected the amount of material deposited in the inner layer. In many cases it is difficult to discriminate between these ecological variations, and real genotypical varieties within a species.

There seems to be a certain histological difference between the inner and the outer layers, but the fact that the latter are so thin, makes difficult to study them in detail. The tissue of the inner layer seems to be histologically uniform, except for the pseudodeltidium and the teeth in some species. In pseudopunctate species, the muscle impressions and their immediate surroundings seem to be impunctate. The tissue itself, however, is not differentiated, the only difference being the absence of the pseudopuncta. In some cases the tissues seem to be unlaminated in ordinary thin sections. Probably this is usually due to the angle under which the laminae are cut by the section. In dry peel sections, the laminae can generally be seen much more clearly, and in these all the parts of the valve appear to be laminated, with the exception of the teeth in some species, and possibly also some of the minor parts of the cardinal region.

PSEUDOPUNCTA

The shells of the Strophomenacea differ from those of all other brachiopods (with the exception of the Estlandidae) in having pseudupuncta in the valves.

They were regarded as open pores by CARPENTER (1856) and BEECHER (1891), and as internal calcareous spines by KOZLOWSKI (1929) and WILLIAMS (1953).

The pseudopuncta consist of a series of cone-shaped sheets, generally meeting at an angle of 90° or less, and a central axis of variable diameter (0,1 mm and less). The cone-sheets are continuations of the growth lines of the tissue of the valves (pl. 14 fig. 5). The apex of the cones can always be seen on the interior surface of the valves. They appear as dots, or as small cones with rounded ends (pl. 7 fig. 15).

The central axis is generally filled with clear calcite. This has led a number of authors into believing that the axes represented massive calcareous spicules in the valve. It is, however, difficult to explain how these spicules could have grown, and why they were formed as discrete spicules. A detailed study of the pseudopuncta in *Leptaena depressa* shows that they are evenly distributed over the interior surface of the valves. The size increases towards the margin. In the case of complete specimens filled with calcite, it is impossible to decide whether the pseudopuncta are spicules or not, as the pseudopuncta in both cases would be filled with clear calcite, and there is no way of discriminating between the unlaminated tissue of the shell and the calcite which fills the space between the valves. The fact that some of the calcite crystals in the pores have the same optical orientation as the calcite fibres in the valve does not indicate that they were formed inside the animal. Such orientated growth of calcite on calcite is common, and does not point to a contemporaneous formation of the two crystals. Orientated crystals are usually just as common on the inner surface of the shell as in the pores. This paper therefore only describes the study of complete specimens where the interspace between the valves was filled with clay or marl, or, in some cases, with marl and calcite. In these specimens it was evident that all the pseudopuncta were filled with matrix, and did not contain any calcareous spicules. In some old specimens the pseudopuncta nearest to the centre of the valve did not have a central axis, and probably this was because they were closed by the growing of the secondary tissue. The possibility of the spicules having loosened from their position or been worn off, can be excluded in these cases, since the specimens show no signs of wear, and the pseudopuncta generally are curved in such a way that massive spicules could not escape. The presence of matrix in the pseudopuncta was proved by colouring the clay minerals with aniline dyes. The contents of the pseudopuncta were coloured in just the same way as the matrix between the valves, and the rest of the specimen remained unstained.

It is worth mentioning that in one of the 67 sectioned specimens, the pseudopuncta are filled with a substance which differs from the matrix in being of a brownish-yellow colour. Tests with aniline dyes show possible traces of clay minerals. The specimen in question was filled both with clay and clear calcite. In both cases the pseudopuncta were filled with the same brownish-yellow substance. This is the only deviating specimen which has been found in the author's material of this species. In some well preserved specimens, the protruding ends of the pseudopuncta in the interior of the valve are perforated. This may be due to wear, but the fact that there usually are perforations, and the absence of all other signs of wear, indicate that the pseudopuncta were hollow.

The pseudopuncta, at least those found in *Leptaena depressa*, must therefore be regarded as cavities for protuberances of the mantle. As for the structure, they resemble the acanthopores of the Trepostomateous bryozoans (CUMMINGS & GALLOWAY 1913) which are regarded as being transformed zooids. Cone sheets similar to those of the pseudopuncta are found in the acanthopores as well (text fig. 1).

Pseudopuncta are found in almost all Strophomenid species. The only exceptions which the author has seen are the genus *Ukoa* ÖPIK (cf. ÖPIK 1932, p. 33), and *Christiania oblonga* (PANDER). In these species, no puncta at all have been observed, in spite of a large material of thin sections.

In most species the pseudopuncta are arranged according to a certain pattern. In specimens with a thin secondary layer, the larger ribs of the external sculpture will often direct the pseudopuncta, so that they are placed in radial rows or segments. This can also be seen in other specimens, and generally in those with large pseudopuncta. The size of the puncta varies considerably, even within the same species. In most species the size even varies in each single valve. *Oepikina dorsata* has large pseudopuncta in the central part of the valves, and smaller ones towards the margin. In *Leptaena depressa* (cf. textfig. 4) it is the other way around.

The largest pseudopuncta are found in *Leptaena*, the smallest in *Oepikina* and in some *Plectambonitids*. These small puncta can scarcely be distinguished from the Dalmanellid endopuncta, even under high magnification, and on well preserved material. It has therefore as yet not been ascertained whether endopuncta can be found in primitive Plectambonitids, such as *Plectambonites*, *Ingria* and others. The material of these genera (from the Lower Ordovician of the Baltic Region) which have been sectioned are all slightly recrystallized, and it is therefore impossible to discriminate between very small pseudopuncta and the endopuncta. The difference between the two types of pores, as defined here, is that the pseudopuncta have cone sheets which

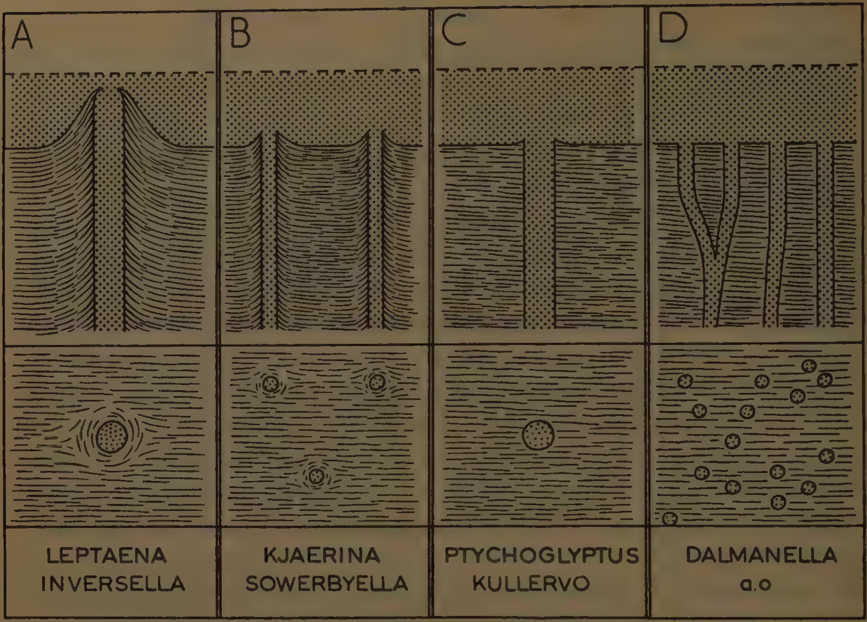

Fig. 1. Diagramatic figures of different types of puncta. *A*. Large pseudopuncta with highly elevated margins. *B*. Small pseudopuncta with elevated margins. *C*. Puncta without, or with only slightly elevated margins. *D*. Endopuncta. The names below the figures indicate typical representatives.

make them protrude from the inner surface of the valves. The apertures of the endopuncta are level with the surface and appear as depressions.

Puncta without, or with only slightly developed cone sheets are found in a number of Plectambonitids, especially *Ptychoglyptus*, while *Leptaena*-like puncta can be found in others, as for instance *Inversella* and *Sampo*. The «eingestochened puncte» described by ÖPIK (1933, pp. 32, 34—35 pl. 6 figs. 1—2) from *Leptelloidea leptelloides* and *L.*(?) *musca*, are also intermediate between the pseudopuncta and the endopuncta. According to ÖPIK, they are filled with matrix right to the bottom (to the external layer). After having studied a large material of specimens belonging to these two species, it appeared that the punctate tissue spread over the whole valve as the animals grew older, and while young specimens were almost devoid of it, old specimens were completely covered. This punctate tissue is probably the internal shell layer. Unfortunately, bad preservation of the histology of these species does not allow a closer study of these interesting structures. The pores found in the Estlandiidae, are of the same type as those in the primitive Plectambonitidae, and the cone sheets are either only slightly developed, or not at all. The amount present of the latter shows the limesecreting capacity of the mantle protuberances which filled the pores.

A gradual transition therefore exists between the endopuncta and the pseudopuncta, and no sharp line of division can be drawn between the two types. If this transition had not been known to exist, the pores found in several Plectambonitids would have been referred to as undoubted endopuncta (pl. 13 fig. 7).

PSEUDODELTIDIUM AND CHILIDIUM

The pseudodeltidium is generally (Beecher 1890, 1891, 1892, Arber 1945) described as a thin plate covering the apical part of the delthyrium. In the material studied by the author, the pseudodeltidium is of a quite different structure. This may be due to the fact that the author has studied older species than those which previously have been described. The species in which the pseudodeltidium has been studied in detail, are *Kiaeromena kjerulfi* (Holtedahl), *K. juvenilis* (Öpik), *Oslomena osloensis*, *Christiania holtedahli* and *Strophomena norvegica*, all from the Middle Ordovician.

The pseudodeltidium of these species consists of an obliquely pyramidal block of calcareous laminae, with sharp edges outwards, and smooth ones inwards. Because of the thin edges, the frontal part of the pseudodeltidium consists of interfingering layers of calcareous tissue and sediment. The fragile edges are easily worn off, and they are rarely preserved in free specimens. In many cases they were probably destroyed before the specimen was buried in the sediment. The material dealt with in this paper consists of specimens preserved in rock, and the pseudodeltidia have been studied either in thin sections, or in artificial casts made by dissolving the calcareous parts in dilute hydrochloric acid.

The lamellae of the pseudodeltidium are parallel to the hinge line, and seem to be part of the area. There is nothing to indicate that the pseudodeltidium was a separate plate different from the ventral valve as indicated by KOWALEWSKY (cf. BEECHER 1891, and ARBER 1945). The growthlines on the area are confluent with those of the pseudodeltidium and in *Kiaeromena kjerulfi* no histological difference can be detected between the area and the pseduodeltidium.

The pseudodeltidium increases in thickness, so that the last, lowest lamellae are deeper than the others. In one species, *Oslomena osloensis*, this growth even isolates the cardinal processes, which seem to be concealed in the pseudodeltidium. The external surface of the pseudodeltidium is generally convex, in *Christiania holtedahli* and *Oslomena osloensis*, it is flat and slightly raised above the area.

The edges of the lamellae are, when they can be observed, bent down towards the dorsal valve. (In specimens with a sharp angle between the areas, the edges point towards the dorsal valve without bending.) They correspond to the similar, generally more fragile edges of the chilidium.

The latter structure is found in many species with well developed pseudodeltidium. It consists of a thin, curved plate which covers the parabolic nothothyrium, and conceals the cardinal processes. It is continuous with the chilidal plates. The strong growth lines with edges pointing towards the ventral valve, are found on the external surface only.

The presence of strong lamellae on the pseudodeltidium and the chilidium and the fact that the edges of these lamellae bend down towards each other, indicates that they were united, probably with a ligament. The presence of a brownish-yellow substance in the frontal part of both the pseudodeltidium and the chilidium adds to the probability of this theory. It might be interpreted as remains of the original ligament tissue. The species in which the pseudodeltidium and chilidium are strongly developed, often have only slightly developed diductor muscles (i. a. *Oslomena osloensis*) or heavy valves (i. a. *Kiaeromena kjerulfi*).

It is evident from the description given in this paper of the pseudodeltidium of the above mentioned species, that at least two types of structures can be found. In the type mentioned, which might be referred to as the b-pseudodeltidium, the growing edge is parallel to the hinge line, while in the other, the «conventional» type, it is roughly parallel to the sides of the delthyrium. This type is called the a-pseudodeltidium. The taxonomic importance of the presences of the different types of pseudodeltidium has as yet not been made clear, owing to the limited material which has been studied. In several cases closely related genera have different types, as for instance *Oepikina* (a)- *Oslomena* (b) and *Leptaena* (a)- *Kiaeromena* (b).

This shows that the presence of a special type of pseudodeltidium probably is of no great importance. The a-pseudodeltidium was very likely a simple cover for cardinal processes and the diductor muscles, while the b-pseudodeltidium served as an attachment for a ligament. It is very improbable that the species with a b-pseudodeltidium should be a related group, opposed to those with the a-type. The taxonomic importance of this feature must therefore be regarded as being at the generic level or lower. The chilidium is also modified in some of the Strophomenids, but not to the same extent as the pseudodeltidium. It generally consists of a thin, curved plate, which more or less completely covers the nothotyrium. Histologically it differs from the rest of the valve in being less fibrous. In the most primitive species (i.a. *Ptychoglyptus valdari*) the chilidium is similar to that found in *Ingria*, and also in the Orthids. In the Leptestidae it is generally very small, if present at all. The so-called «chilidal plates», which form parts of the cardinal process in this family, probably have no connection with the chilidium. In more highly developed Strophomenids, these plates possibly develop into cardinal processes, and in spite of this, these species have a chilidium, which is histologically identical with that of the primitive Plectambonitids. The «chilidal plates», therefore, can hardly represent a reduced chilidium.

In the species with double cardinal process (Strophomenidae), the chilidium usually has a thin median fold, corresponding to the slit between the cardinal processes. In primitive species, this fold is hardly developed (*Oepikina*), and in others the fold is present, but the distance between the chilidium and the cardinal processes is comparatively large (i. a. *Kiaeromena juvenilis*, pl. 7 fig. 17 and *K. kjerulfi*, text fig. 41). In the more highly developed species, the chilidium is very thin, and the distance between the cardinal processes and the chilidium is extremely small, so that the fold fits into the slit. Because of the small interspace between them, it is difficult to ascertain the presence of the chilidium, except in thin sections because it forms a perfect cast of the posterior side of the cardinal processes (i.a. *Leptaena depressa*, pl. 14, fig. 8).

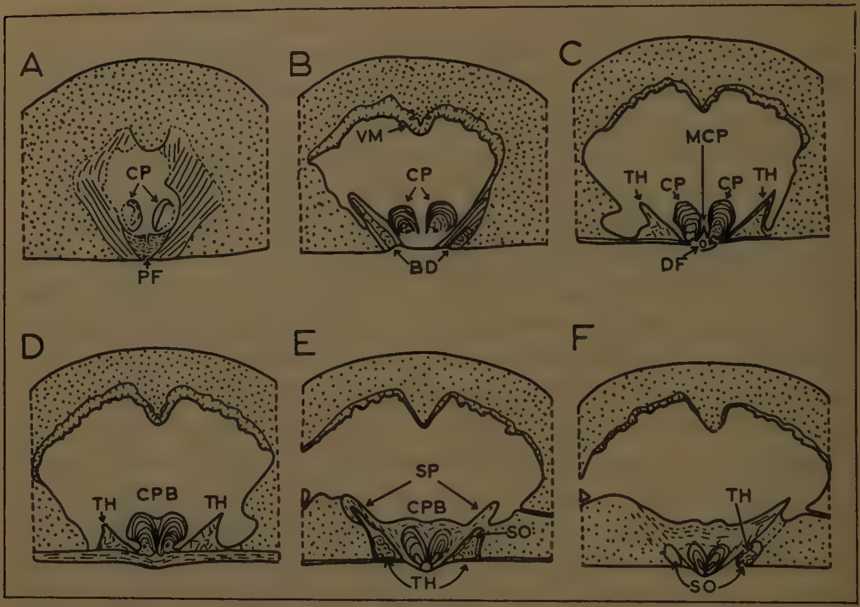

Fig. 2. *Oepikina dorsata* (BEKKER). Six horizontal, parallel sections of a small specimen from zone C2 in Esthonia, showing the structure of the teeth and the cardinal processes. *Abbreviations:* CP — Cardinal processes. CPB — Posterior shaft of the cardinal processes. BD — Base of the teeth. DF — Dorsal foramen. MCP — Median cardinal process. FF — Ventral pedicle foramen SO — Sockets. SP — Socket plates. TH — Teeth. VM — The special tissue of the ventral muscle impressions. Magnification about 5x.

THE TEETH

The teeth are defined as the secondary tissue deposited in the corners between the hinge line (area) and the dental plates.

In many thin-shelled species, and in most young specimens, the teeth are not developed, or they are present only as an inconspicuous thickening of the anterior part of the dental plates.

The histological structure of the Strophomenid teeth has previously not been well known. Except for the Stropheodontidae, which have been described in detail by WILLIAMS (1953), most others were supposed to have had teeth built up of laminated tissue. The teeth are subject to considerable wear, and it can be expected that some differentiation has taken place to compensate this.

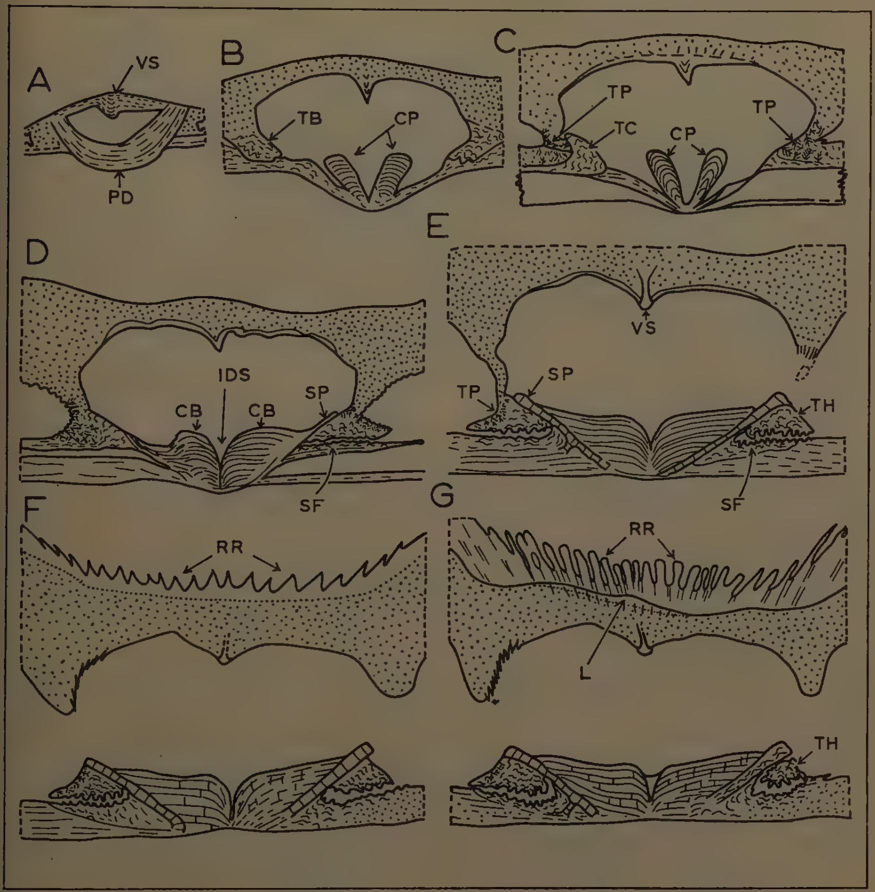

Fig. 3. *Strophomena planumbona* Hall. Seven horizontal, parallel sections of a specimen from the Maysvillian at Blanchester, Ohio, U.S.A. Section *A* cut only through the ventral valve, near the apex, the other sections cut through both valves. Note the assymetric development of the teeth, especially that the left one consists of both punctate and fibrous tissue, whereas the punctate tissue is found only in the upper, basal part of the right one.

Abbreviations: CP — Cardinal processes. CB — low, posterior shafts of the cardinal processes. IDS — furrow between the cardinal process continuing posteriorly. L — Growth-lamella with matrix in a pocket. PD—Pseudodeltidium RR — Radial ribs of the external sculpture. SP — Socket plates, well differentiated from the rest of the dorsal valve. TB — Bases of the teeth. TC — Teeth tissue consisting of irregular fibres without puncta. TH — Teeth. TP — Teeth tissue consisting of laminated tissue with small pseudopuncta. SF — Lining of socket walls consisting of tissue similar to that found in the teeth. VS — Ventral septum. Magnification about 5x.

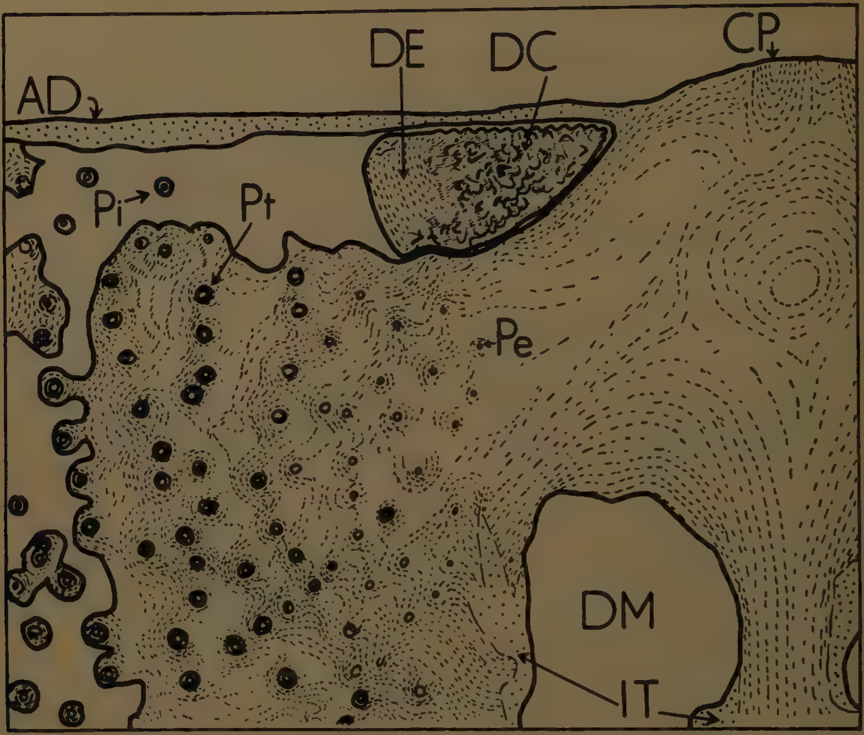

Fig. 4. *A section parallel with and near to the inner surface of the dorsal valve of Leptaena depressa.* The figure shows the structure of the teeth, and the shape and distribution of the pseudopuncta. The specimen is from the Mulde Marl (Upper Wenlock) at Tegelbruket, Frøjel, Gotland.

Abbreviations: AD = Dorsal area. CP = Cardinal process. DC = Central portion of teeth, composed of irregular vertical elements. DL = Laminated, lateral portion of teeth. DM = Dorsal muscle impressions (above the plane of the section) IT = Nonlaminated tissue around the muscle impressions. Pe = Small, central pseudopunctae. Pi = Protruding pseudopunctae, which appear isolated in the section. Pt = Large, distal pseudopunctae.

A number of species, mostly Plectambonitids, have simple teeth consisting of laminated tissue, with the laminae parallel to the sides of the more or less triangular teeth. In this group the wear seems to be compensated by double teeth in some genera, or denticulations along the hinge line.

Real specializations of the tissue of the teeth seem to be restricted

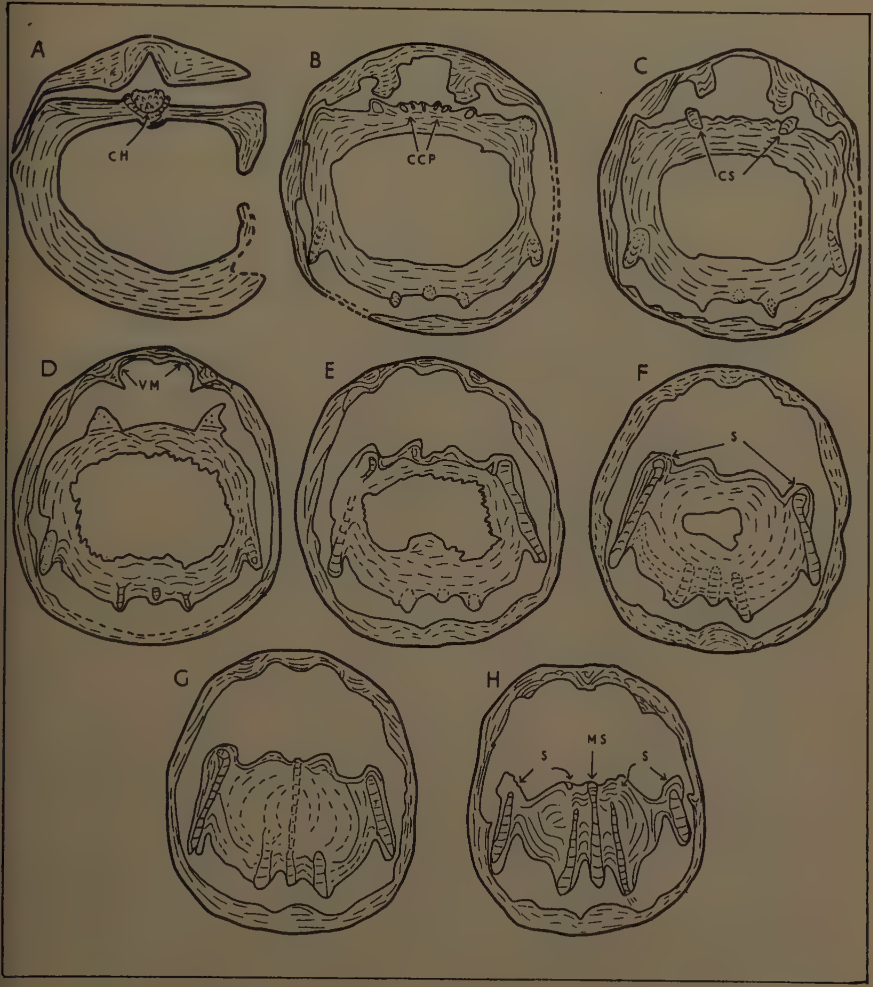

Fig. 5. *Christiania oblonga* (PANDER). *8* parallel section of one specimen. From zone B3 (?) at Popovka, near Leningrad. (cf. textfig. 26B).

Abbreviations: CCP = Cardinal processes, denticles on the socket plates. CH = Chilidium (Most of these structures are destroyed by recrystallisation) CS = Socket plates. MS = Median septum. S = Lateral septa. VM = Ventral muscle impressions.

to the Strophomenacea. In fact, none of the species which for certain are known to belong to this superfamily, seem to have teeth consisting of laminated tissue only. When only the laminated tissue is found, it is from the dental plates, and the teeth themselves are not developed. In all the species which have been studied. (*Oepikina dorsata*, text fig. 2, *Kiaeromena kjerulfi*, text fig. 41, *Strophomena planumbona*, text fig. 3, and *Leptaena depressa*, text fig. 4), the teeth consist of specialized fibrous tissue. Only in the latter species (and possibly *Kiaeromena kjerulfi*) parts of the teeth consist of laminar tissue. In *Kiaeromena kjerulfi*, the teeth are elongate, parallel to the hinge line, and consist of irregular lamellae and layers of calcareous tissue, perpendicular to the area. The teeth are small in proportion to the size of the valves.

In the other species which have been studied, the teeth are triangular, and consist of irregular fibrous tissue, with curved dark lines, parallel to the surface, and some small pseudopuncta. The border between the dental plates and the teeth is sharp. The side of the teeth facing the socket plate is smooth, whereas that facing the inner side of the area generally has irregular raised ridges which are especially strong in gerontic specimens. The «semidenticles» do not seem to correspond to any histological structure in the interior of the teeth (as for instance the Stropheodontid denticles), they are merely ridges on the surface of the teeth.

The anterior wall of the socket is smooth, and generally has no furrows corresponding to the «semidenticles». At the very apex of the teeth, the side facing the socket plates might also be «semidenticulated» (pl. 12 fig. 8). In some species (*Strophomena planumbona* a.o.) the sockets are lined with tissue similar to that found in the teeth. In this case, a gradual transition is found from the ordinary, pseudopunctate laminated tissue to the fibrous with smaller pseudopuncta.

Since the typical structure of the teeth is fully developed in adult specimens only, and as the histology only has been studied in a limited number of species, it is difficult to use this feature in the systematics at present, even if it obviously is of high potential value.

CRENULATIONS OF THE HINGE LINE

The crenulations of the hinge line in the Strophomenids have recently been thoroughly described by SCHMIDT (1951) and WILLIAMS (1953). The former author is of the opinion that a crenulated hinge line can be found in several groups, and that the family Stropheodontidae is polyphyletic. WILLIAMS regards this family as being strictly monophyletic. This difference of opinion is due to the fact that SCHMIDT has compared all types of crenulation of the hinge line, even those of the Plectambonitacea, whereas WILLIAMS only has considered the crenulated teeth plates which are secondarily ancylosed to the hinge line.

The author's studies of this feature have made it possible to distinguish between several types of crenulation within the Strophomenids. Some of the types have been described by previous authors.

1) The *Plectambonites*-type, in which the whole hinge line is uniformly denticulated in all specimens, whether young or old. The denticles seem to be formed by small pseudopuncta strengthened by deposition of secondary calcareous tissue. (*Plectambonites*, *Ingria*).

2) The *Plectodonta*-type. Denticles decreasing in size from the deltidium towards the cardinal angles, which seldom or never are reached by the denticulation. The young specimens are generally not denticulated, or considerably less than the older ones. The denticles seem to consist of simple protuberances from the hinge line. No central body has been observed, and this indicates that they are not homologous with the pseudopuncta. (*Plectodonta*, *Eoplectodonta*, *Alwynella*, *?Sampo*).

3) The *Sowerbyella ringsakerensis*-type, which consists of large pseudopuncta along the hinge line. The size of the pseudopuncta decreases from the cardinal angles towards the central part of the hinge line, which is not denticulated. There may be some relationship between this type and the spines of *Chonetes*. It is worth mentioning that some species of *Chonetes* have the deep ventral muscle impressions which are typical for the members of the Sowerbyellinae, and in some Sowerbyellas the ventral interior shows a strong median septum and indistinct muscle impressions, resembling the interior of *Chonetes*. The material available is too limited to prove whether these species are homeomorphs of *Chonetes*, or if they are the ancestors of that group.

It is doubtful whether these crenulations really acted as supports for the articulations of the valves. (*Sowerbyella ringsakerensis* sp. n., p. 94, and *Sowerbyella* sp. of SCHMIDT 1951, pl. 51, fig. 8).

4) The *Stropheodonta*-type. This type has been described in detail by WILLIAMS and SCHMIDT (l.c.), and it is not necessary to repeat their description here. In contrast to the types mentioned

above, the denticules are found only on the dental plates in Stropheodontidae, which, however, may be extended nearly to the cardinal angles. In the dorsal valve, there are grooves in the socket plates to accomodate these denticles. In this type, too, the denticulation increases with the age of the specimens. The type appears to be restricted to the family Stropheodontidae, with the exception mentioned below.

These four types of crenulation must be regarded as genetically different trends of development. The first three types also differ from the last one in that the crenulations are restricted to the hinge line in the former, while there is a crenulation of the teeth plates in the latter. The Stropheodontid type can therefore rather be compared to the double teeth of the Leptestininae, than to the three other types of denticulation described here. The Stropheodontid crenulations are probably homologues of the «semidenticulations» in the other Strophomenacea, and these crenulations are therefore not a characteristic feature of the family Stropheodontidae. It is the coalescence of the dental plates (and the socket plates) with the hinge line which distinguishes this family from the rest of the Strophomenacea. One can find Strophomenidae which have much more strongly denticulated teeth than the primitive members of the family Stropheodontidae.

The above shows that there is a gradual transition between the more primitive Stropheodontids and the Strophomenidae. This might to a certain degree affect the validity of the family Stropheodontidae. It appears that all the known stropheodontid lineages lead back to comparatively simple uniform types (WILLIAMS 1953a, p. 19), and this seems to support the theory of the family being of a monophyletic origin. The presence of Middle Ordovician species which are more highly developed than the previously oldest known species from the Uppermost Ashgillian and Llandovery, and the widespread occurrence of semidenticulation in the Strophomenidae, might, however, indicate that the Stropheodontidae are polyphyletic.

Owing to the lack of material of the younger (Devonian) species, the author is unable to determine which lineages of the family Stropheodontidae are polyphyletic. After having studied the material described in this paper, it seems fairly evident that the majority of the genera included in the family (as defined by WILLIAMS 1953) belong to a genetically homogenous group. Some minor groups may prove to be homeomorphic real strophomenids.

CARDINAL PROCESSES

The cardinal processes of the Strophomenida have been extensively used for classification of the group (cf. WILLIAMS 1953, pp. 6—10). The Plectambonitacea have simple (Plectambonitidae and Taffinidae) or complicated, trifid cardinal processes (Leptestidae) or none at all. The Strophomenacea and Christianidae generally have bifid cardinal processes. Some Leptestids (i. a. *Leptelloidea*(?) *musca* ÖPIK) also have this structure.

The simple cardinal process of the Taffinidae and Plectambonitidae does not show any special features, but in some Leptestids the cardinal process is perforated by a dorsal foramen (cf. text figs. 21, 23), and it is ancylosed to a pair of chilidal plates, so that it appears to be trifid. The dorsal foramen is discussed below (p. 51). In the Christianidae and in *Oepikina* the bifid cardinal processes have developed from this trifid structure. This is proved by the gradual transition between the two types found in *Christiania oblonga,* and by the rudimentary median cardinal process and dorsal foramen found in *Oepikina.* It is not yet clear whether the bifid cardinal processes developed from the chilidal plates themselves, or from small denticulations on them.

In some Strophomenidae (*Rafinesquina* a.o.) one finds another type of cardinal processes which cannot have been developed directly from that of the Leptestidae. It consists of a pair of long, thin, subparallel ridges strengthened by secondary tissue. The author believes that this type was developed as septa on both sides of the dorsal groove, (cf. text fig. 7). The presence of a dorsal groove in several larval valves of Strophomenids (pl. 7 fig. 5) gives good support of this theory. However, there is at present not enough proof of the theory to justify its use as a basis for the classification of the Strophomenida. It is worth mentioning that the oldest true Strophomenids (except *Oepikina*), *Rafinesquina* (?) *llandeiloensis* and *R.* (?) *maccallumi* REED, belong to this group, with long, plate-like cardinal processes. A continuous line of development seems to lead from these species to *Kjaerina, Hedstroemina* and to the earliest Stropheodontids.

The diductor muscles are attached to the cardinal processes. Their effectiveness is increased if the cardinal processes are high, and inclined posteriorly (cf. p. 42). One therefore often finds species with

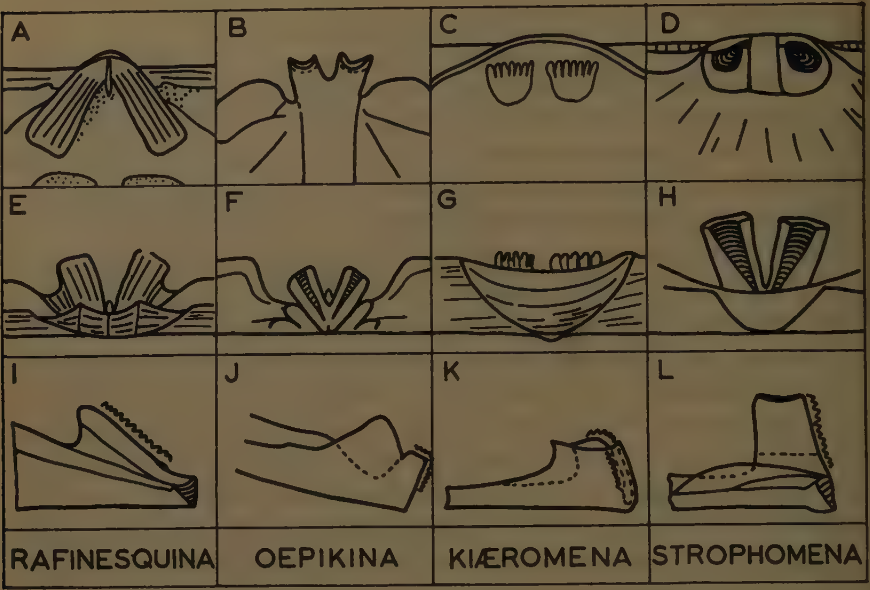

Fig. 6. Diagramatic figures of the cardinal processes in some Strophomenid genera. Figs. *A*, *B*, *C*, *D* are seen from above, *E*, *F*, *G*, *H* from the anterior side of the specimens, and *I*, *J*, *K*, *L* from the side. *A*, *E*, *I* are from *Rafinesquina alternata*, from the Maysvillian, at Cincinnati, Ohio, U. S. A. *B*, *F*, *J* are from *Oepikina dorsata* (BEKKER) from zone C2 in Esthonia. *C*, *G*, *K* are from *Kiaeromena kjerulfi* from zone 4bβ in the Oslo—Asker district, Norway. *D*, *H*, *L*. are based mainly on *Strophomena steinari* sp. n. from the Coelosphaeridium beds in the Ringsaker district, Norway. The actual muscle attachment is indicated by a zig-zag line.

high cardinal processes, curved posteriorly, and with the muscle attachments on the posterior side (cf. text fig. 6 B, F, J.). This feature is generally connected with the development of «forked» cardinal processes. Since the muscle was bent over the top of the processes, lateral ridges were necessary to keep the muscle in position, so that it should not slip off. Seen from above, these lateral ridges give the cardinal processes a forked appearance (text fig. 6 B). Seen from the notohtyrium (text fig. 6 F), the lateral plates converge downwards. When the cardinal processes are built in this way, it is only a mechanical adjustment of small systematic value, as it can be found in several, probably unrelated groups (*Oepikina*, *Strophomena*, *Kjerulfina*, and the Stropheodontids).

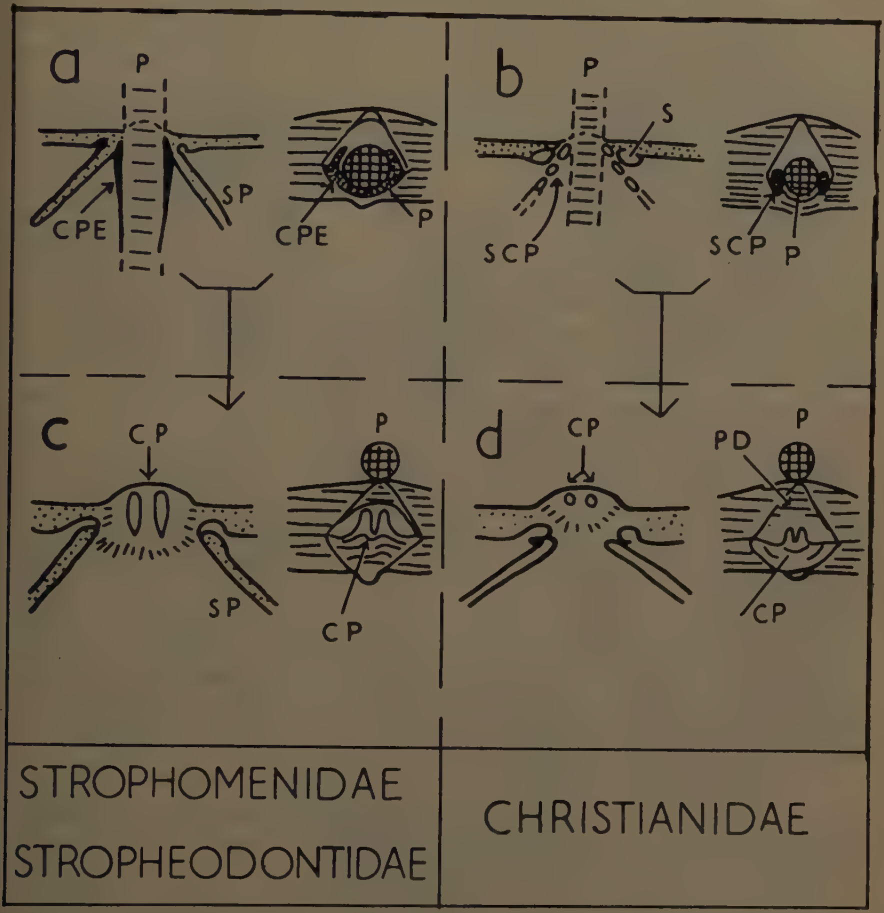

Fig. 7. The development of the cardinal processes. A—B. Larval stages. C—D. Adult forms. (It is possible that also the CPE developed from the socket plates, and the difference between the two types is smaller than supposed).

Abbreviations: CP = cardinal processes, CPE = Larval cardinal processes, formed along the sides of the pedicle. P = Pedicle, PD = Pseudodeltidium, S = Sockets, SP = Socket plates, SCP = Nodes on the socket plates, later developed into the cardinal processes.

In *Rafinesquina* (text fig. 6 A, E, I) the muscle attachment surface is inclined at 30—45°, and is broad and finely longitudinally striated. Because of the very low a/a' balance (1) (see below, p. 43) in this genus, the muscle attachments had to be large.

In *Kiaeromena*, and probably also in *Leptaena*, the muscle attachment surface was steeply inclined, and, instead of being kept in place by lateral ridges, the muscles were secured by a number of deep furrows which widened out towards the bottom (text figs. 6 C, G, K, pl. 14 fig. 9).

THE VASCULAR SYSTEM

Several authors have described vascular systems both of recent and fossil brachiopods. In spite of this, little systematic work has been done on this subject, although many authors have stressed the importance of the vascular system for the taxonomy. This is partly due to the incomplete knowledge of the vascular system in most fossil brachiopods. The vascular system is only found in gerontic specimens, and even in most of these the impressions of the vascula are incomplete. The individual and interspecific variations of the vascular systems have not been studied either.

Because of these difficulties, our knowledge of the vascular systems of the brachiopods and their taxonomic importance is still very limited. The author will therefore not attempt to make important changes in the present systematics of the brachiopods on the basis of the vascular system alone.

The vascular systems of recent brachiopods have been studied by i.a. DESLONGCHAMPS 1864, LACAZE-DUTHIERES 1864, and DAVIDSON 1886—88. However, none of these papers are primarily devoted to the study of the vascular system. TERMIER & TERMIER (1942), and especially ÖPIK (1934) have studied the vascular systems of fossil brachiopods, and there are a large number of figures and notes in SCHUCHERT & COOPER (1931), HALL & CLARKE (1892), DAVIDSON (1851—1886), REED (1917) and in several other papers. In addition to the author's own observations, which mainly are based on British and Scandinavian material, the above mentioned papers are the main sources for the following notes.

The terminology for the vascular system of recent brachiopods is due to DESLONGCHAMPS (1864). It is based on the Terebratulids which have two pairs of vascula in each valve. The marginal vascula which generally are the largest, are the lateral venous sinuses, and the central ones are the median venous sinuses. All vascula emanate from

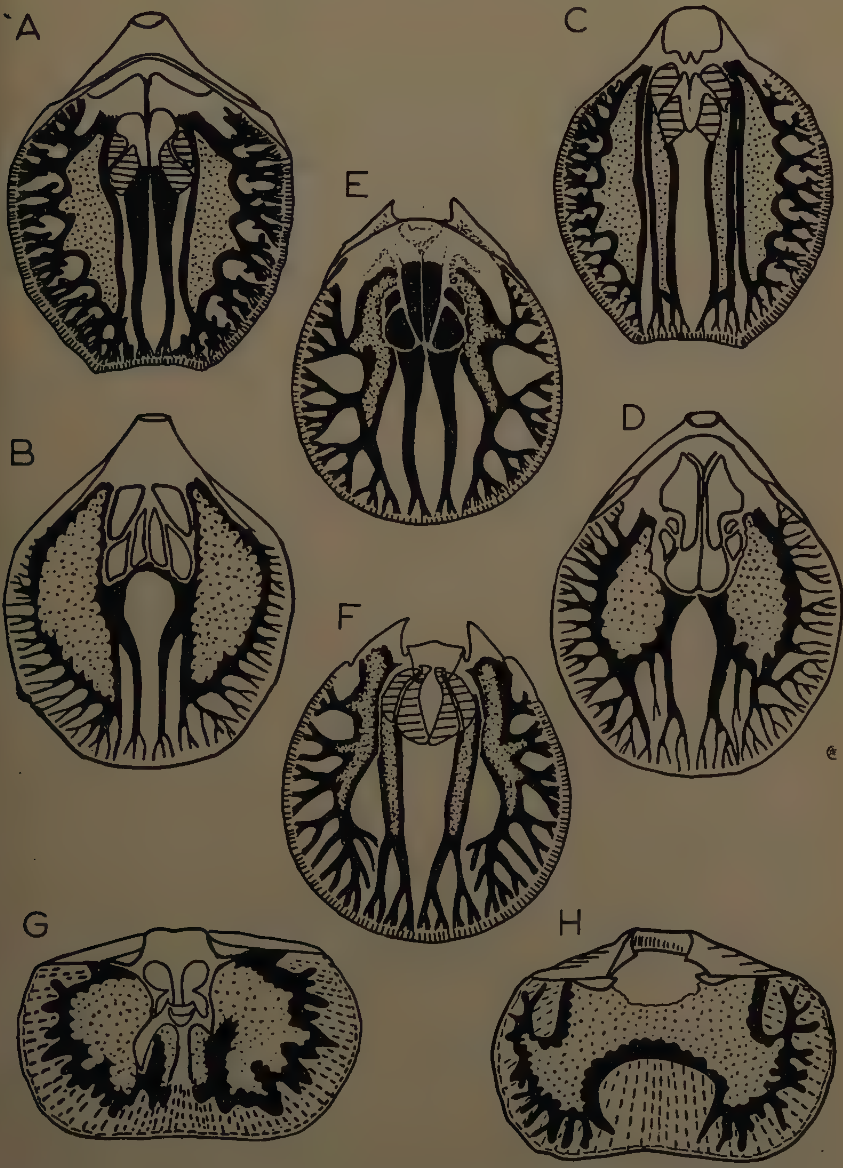

Fig. 8. *The vascular system of some recent brachiopods.* A—B. *Waldheimia flavescens.* dorsal and ventral view. From Davidson 1886—1888, pl. 7, figs. 15—16. B.D. *Terebratulina caputserpentis*, dorsal and ventral view. From Davidson 1886—1888, pl. 4, figs. 8—9. E—F. *Waldheimia cranium*, dorsal and ventral view. From Davidson 1886—1888, pl. 13, figs. 1—2. G—H. *Megerlia truncata*, dorsal and ventral wiew. From Davidson 1886—1888, pl. 19, figs. 18—19. Ovaria are dotted, vascula black in all figures.

a point near the apex of the shell, and terminate in a large number of minor branches all along the margin of the shell.

Öpik's terminology for the vascular system of the fossil brachiopods is mainly based on the possibly primitive vascular system of the Clitambonitids. In this group, there are three pairs of vascula which are different in the dorsal and ventral valves. (In all described recent brachiopods, the vascular system is identical in both valves). Öpik's three pairs are termed vascula media, vascula myaria (spondylaria), vascula cruralia (dentalia); the terms in brackets refer to the ventral valve.

The vascula media seem to correspond to the median venous sinuses, and the lateral venous sinuses to the vascula myaria or the vascula cruralia, or both.

According to Öpik (1933, 1934) the vascular system of the most primitive articulated brachiopods was polypalmate, and consisted of a comparatively large number of radiating vascula, corresponding to the ribs of the external sculpture. The number of main vascula was then reduced to six, that is three pairs, and later even to two (one pair). In the latter case, the terminal vascular branches are formed either as an arch (vascula arcurata) parallel to the margin of the valve, or by bifurcation of the vascula (vascula bifurcata). The importance of this feature has not been studied in detail, and transitional forms are quite usual. Vascula arcurata are common in connection with ovarian impressions while vascula bifurcata generally are found in specimens devoid of such.

There is good reason for revising the terminology as regards the number of main vascula. The author therefore propose to restrict the term polypalmate to forms with more than six radiating main vascula, and to term the forms with reduced vascular system, hexapalmate, tetrapalmate and dipalmate respectively. Using this terminology, most terebratulids have a tetrapalmate system, while some, like *Kraussina rubra* have a dipalmate one. Compared to Öpiks terminology, his polypalmate comprises polypalmate and hexapalmate of the present terminology, and his oligopalmate tetra- and dipalmate.

The so-called ovarian impressions are very common. In most recent brachiopods the ovaria are found inside the main vascula, and, as far as the author has seen, they seldom leave impressions in the calcareous valve.

In some cases there is a possibility of structures described as ovarian impressions really being the impressions of other organs. However, since we have no proof of the existence of such organs, all the impressions of this kind are regarded as being ovarian in this paper.

The ovaria are always intimately connected with the vascula. The ovarian impressions found are generally bounded by a groove, which is confluent with the vascular grooves. The development of the ovaria is different in the various groups of brachiopods, and might even be different within the same group (see the vascular system of the Orthacea).

Öpik (1934) believed that the ovaria of the ventral valve of the Orthacea (and probably similar ovarian impressions in other groups) were transformed vascula spondylaria. After having studied the development of the ovaria of the Orthacea and other fossil brachiopods, the author does not agree with him on this point. The ovaria are probably differentiated from the vascula, and are always found within them. The ovarian impressions are not, like the muscle impressions, devoid of pseudopuncta, if such are present in the valve (as for instance in *Leptaena*).

The ovarian impressions are generally ovoid or elliptical, or circular. Sometimes they are of an irregular shape, with ridges parallel to the sculpture of the exterior of the valve. Some of them have a complicated net of vascula inside. They are often bounded by an elevated ridge with a vascular groove on the outside.

Vascula terminalia: In recent brachiopods, the vascula terminalia ends at the base of the cilia. (Text fig. 9, L, M.). Generally there is a large number of cilia, and each of them has a special vascular branch. The ciliar grooves are smooth and uniform. Now and again the basal ends are swollen, corresponding to the shape of the base of the cilia.

In the fossil brachiopods we are dealing with, there are several types of cilia, or, to be correct, ciliar grooves. In the Clitambonacea the ciliar grooves are simple, like those of the Terebratulids, except that they are stronger. Each groove seems to correspond to a rib in the external sculpture. The ciliar fringe, the part of the inner margin of the valve where the ciliar grooves replace the vascula terminalis, is rather broad in most Clitambonitids, and a gradual transition is found from the vascular grooves to those of the cilia.

At least most of the Orthacea have fewer ciliar grooves than ribs in the external sculpture. In some cases (such as *Orthis kuckersianus*

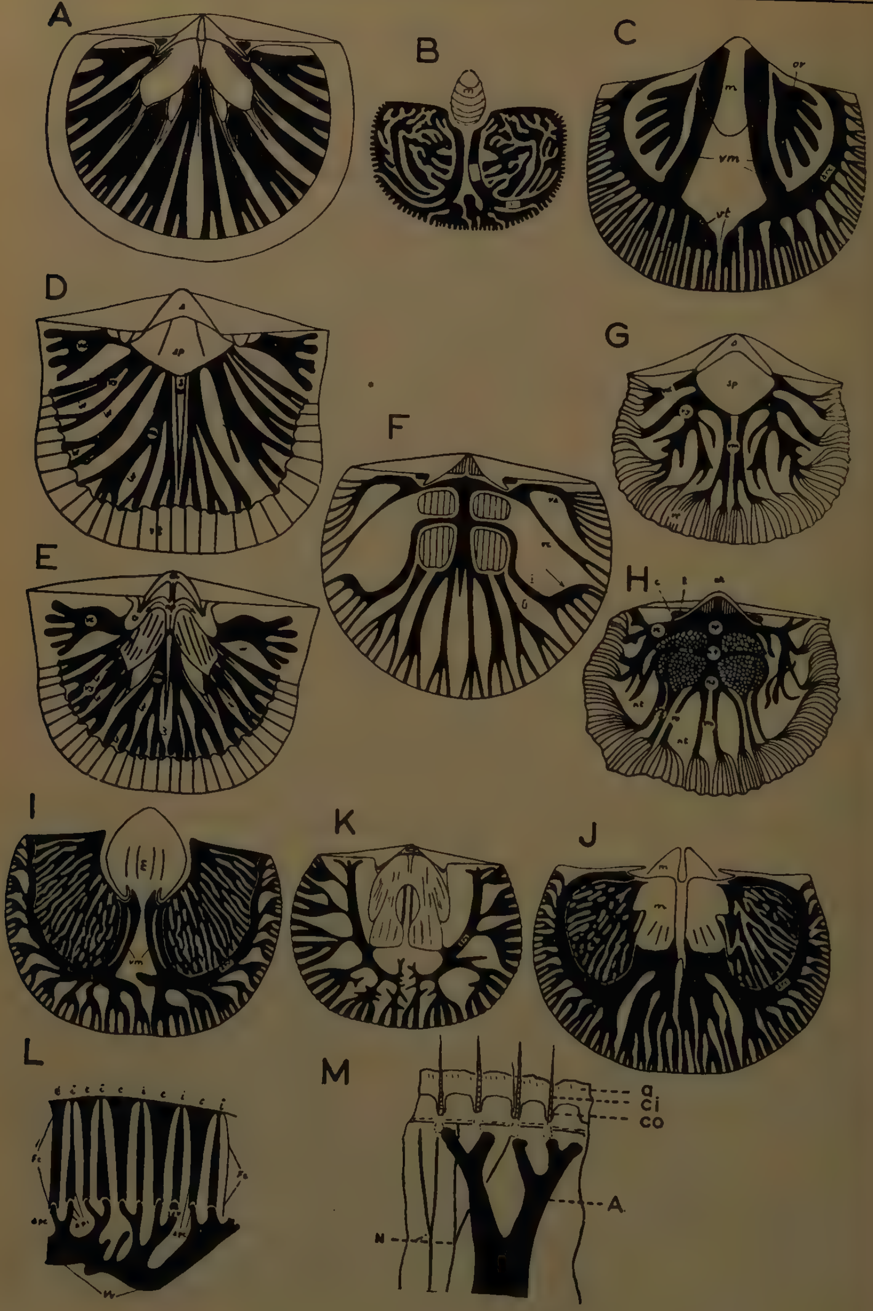

Fig. 9.

cf. ÖPIK 1934, textfig. 54) the cilia were probably differentiated into two types, placed alternatively around the margin, each of them corresponding to 1—2 vascular branches. These cilia were probably much more highly specialized than those of the recent brachiopods.

In the Strophomenids there are usually no vascula terminalia close to the margin. Generally the external sculpture also continues for a short distance on the inner surface, until it is concealed by the secondary tissue. Possibly the grooves formed by the ribs were the ciliar ones. In some species, *Eoplectodonta acuminata*, *Grorudia? glabrata* and *Ptychoglyptus valdari*, very strong and deep ciliar grooves are found along the margin, impressed not only in the primary valve, but also in the secondary tissue. In *Ptychoglyptus valdari* every ciliar groove corresponds to one of the terminal branches of the vascular system. In *Grorudia? glabrata* only every other or every third ciliar groove corresponds to a vascular branch. (Pl. I, figs. 1, 2, 12, Pl. III, fig. 9.) In *Eoplectodonta acuminata* the vascula terminalia are not developed. In all three species the ciliar grooves seem to correspond to the major ribs of the external sculpture.

LAMONT (1934) believed that the external sculpture, which reflected the dimensions of the cilia, also showed the grain-size of the sediment in which the specimen lived.

Fig. 9. *The vascular system of some Orthids and Clitambonitids, and the terminal vascula.* A. *Finkelnburgia* sp. dorsal valve. From ÖPIK 1934, textfig. 23. B. *Paurorthis parva* (PANDER), ventral valve. From ÖPIK 1939, textfig. 2. C. *Billingsella lindströmi* (LINNARSON) ventral valve from ÖPIK 1934, textfig. 15. D—E. *Estlandia marginata*, dorsal and ventral valve. From ÖPIK 1934, textfig. 14. F. *Orthis calligramma*, dorsal valve. From ÖPIK 1934, textfig. 16. G—H. *Clitambonites schmidti epigonus*, dorsal and ventral valve. From ÖPIK 1934, textfig. 8. I—J. *Dolerorthis osiliensis* dorsal and ventral valve. From ÖPIK 1934, textfigs. 17—18. K. *Dinorthis* sp. ventral valve. From ÖPIK 1934, textfig. 21. L. *Cyrtonotella kukersianus* terminal vascula. From ÖPIK 1934, textfig. 54. M. *Terebratulina caputserpentis*. Terminal vascula. From DESLONGCHAMPS 1864, pl. 1, fig. 5.

Abbreviations: A = Arteries. a = growing edge of shell. Arc, ac = vascula arcurata. c = costae. Ci = cilia. Co = muscular attachment of the mantle. iv = intervascular septa. i = intercostal spaces. Fe = marginal vasculae (?). M.m. = Muscular impressions. N = veins. ov. = Ovarian (?) impressions, vd = vascula dentalia. vm = vascula media. vt,Vv = vascula terminalia. vy = vascula myaria and vascula spondylaria. vc = vascula cruralia. apc = costal apophyses. api = intercostal apophyses.

However, we must remember that the size and number of cilia do not always correspond to the coarseness of the external sculpture. The Orthids have already been mentioned, and *Eoplectodonta acuminata* also had fine sculpture, but coarse cilia.

THE DEVELOPMENT OF VASCULAR SYSTEM IN THE BRACHIOPODA

Inarticulata. Several different vascular systems are found among the inarticulate brachiopods. A detailed study of this subject is outside the scope of this paper. A point worth mentioning, however, is the marked difference between *Lingula* and *Obolus.* WALCOTT (1912, p. 311) believed the vascular systems to be similar. This assumption was based on the erroneous interpretation of the species *O. appolonis* given by MICKWITZ. Figures of other, less derived species of *Obolus* (i. a. *O.* (*Broeggeria*) *salteri* cf. WALCOTT 1912, pl. 13 fig. 1 m) show that this genus has 4 vascula in the valve, and not 2 badly defined arches like *Lingula.* The difference between *Obolus* and the articulate brachiopods only lies in details as to the branching, while the vascular system of *Lingula* is fundamentally different. This brings to mind PERCIVAL's assumption (1944), that *Lingula* does not belong to the brachiopoda proper.

Clitambonitacea. (Textfig. 9). The complicated vascular systems of the Clitambonitacea have been described in detail by ÖPIK (1934). He points out the resemblance to *Finkelnburgia,* which he believes to be an ancestor of the group. The vascula which were found were hexapalmate to polypalmate. No differentiated ovarian impressions could be seen, and they are probably placed in the broad irregular vascula. In the Estlandidae (textfig. 9 D—E) the vascula cruralia do not terminate into ciliar grooves, and this may indicate that they were specialized into ovaria. The fact that the vascula cruralia are so strongly developed in contrast to the other vascula in *Rauna* also seems to indicate that the vascula cruralia had a function which was different from that of the other vascula.

Orthacea. (Textfigs. 9—10). In the Orthacea the vascular systems vary considerably. In the fully developed normal type, the ventral system consists of two large ovoid ovarian impressions, surrounded by a fringe of terminal vascula. Probably there are no differentiated vascula media at all. In some cases the median branches of the terminal vascula are longer than the others. That, however, is probably due to the shape of the ovaria, and not to the presence of separate vascula. In the dorsal valve there are usually three pairs of vascula. In some species only one or two of them are developed. Ovarian impressions are found in most younger species, two lateral ones, placed near the hinge-line and a third, which is more rarely developed, between the forking branches of the vascula media.

The development of the dorsal ovaria through fusion of the vascula myaria and vascula cruralia has been described in detail by Öpik 1934. A number of beautifully preserved specimens were used to illustrate this (l.c. pl. 48, textfig. 55). It has therefore definitely been proved that the lateral dorsal ovaria were developed in the vascular arch formed by the fusion of the two vascula. It is probable that the third, posteromedian ovarium was developed in a similar way, by the fusion of the median branches of the vascula media. There is, however, no definite proof for this theory.

The distribution of the various types of vascular systems among the Orthacea will require much further study. Species with either two or three dorsal ovaria or none at all, are found in closely related groups, and the rather limited material dealt with in this paper does not indicate any sexual dimorphism which might explain this feature. Most Orthids seem to have either two ovaria or none at all, and the Dalmanellids generally have three.

The development of the ventral vascula of the Orthacea is quite different from that of the dorsal one. The oldest known species (of *Billingsella* and *Oligomys* (textfig. 9 C, 10 A)) have vascular arches. In some younger possibly more primitive species of *Nicolella* (cf. Davidson 1871, pl. 36 fig. 14) and *Orthis* s.s., there is a different system, consisting of a large number of radiating vascula which do not branch until near the margin. Each of the radiating vascula in this polypalmate system corresponds to one of the ribs in the external sculpture. Some of the species which have this type of ventral vascular system, might also have a similar, polypalmate dorsal system. However, the material does not give any definite proof of this, since it often is impossible to discriminate between the vascula and the sculpture showing on the internal surface of the valves in the material available.

Through intermediate forms, found i.a. in *Dolerorthis psygma* Lamont & Gilbert and species of *Glyptorthis*, this «*Nicolella*»-type

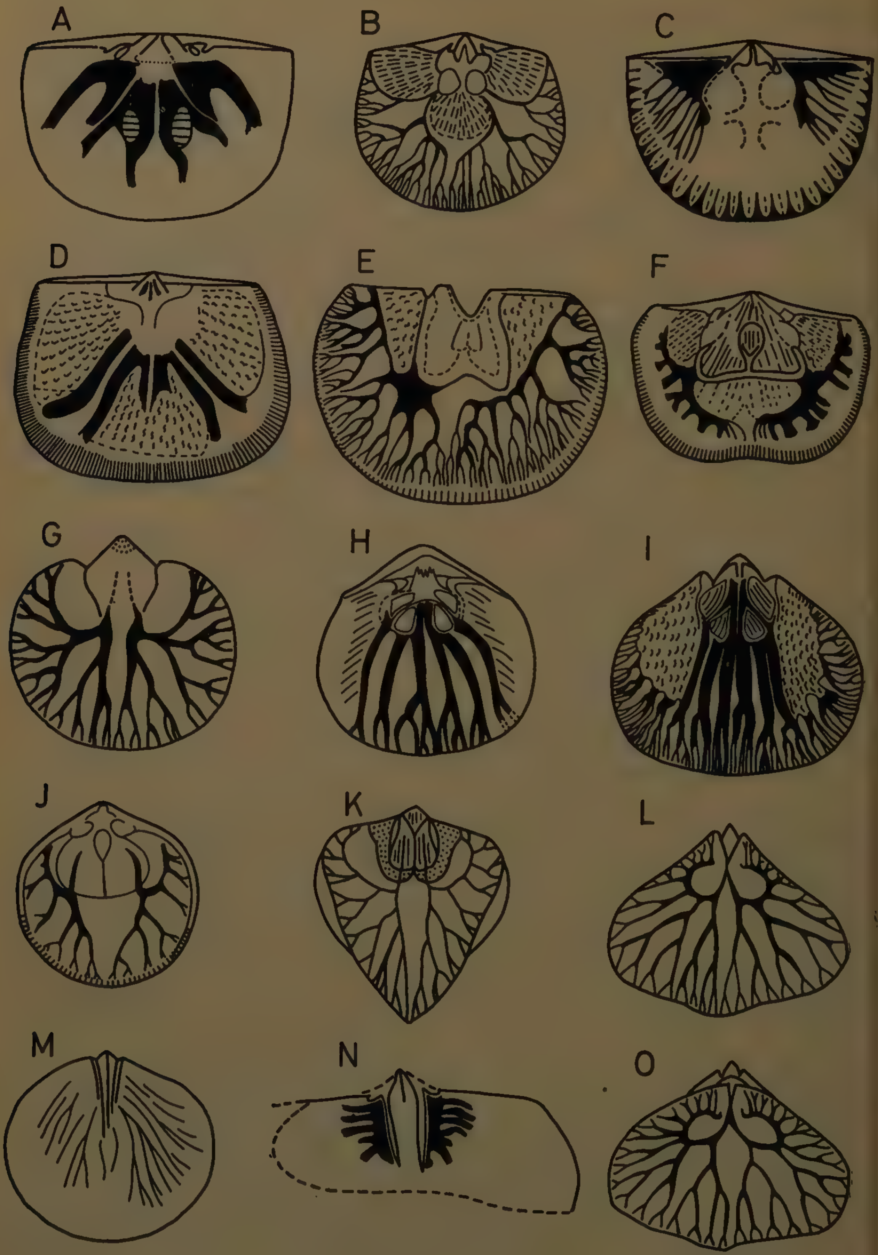

Fig. 10.

is united with the ordinary one. These intermediate species have comparatively small radially striated ovarian impressions around the ventral muscle impressions, fringed with long terminal vascula. The ovaria in the dorsal and ventral valves of the Orthacea have therefore developed in different ways.

The development of the ventral vascular system seems to have been «slower» than that of the dorsal one. In a specimen of *Orthis* cf. *calligramma* from the Baltic Lower Ordovician, with a dorsal system similar to that figured by ÖPIK (1934, textfig. 16), with the vascula myaria and vascula cruralia on the point of fusing, the ventral system is still on the «*Nicolella* stage». In a *Glyptorthis* species from the zone 4b*α*, in the Oslo Region, the ventral system is in the intermediate stage, with small, indistinct ovaria, and long terminal vascula. The dorsal system of the same specimens are completely developed with three ovaria. It is also worth mentioning that in *Dolerorthis osiliensis*, the ventral ovaria cover most of the internal surface of the valve even in young specimens, whereas the relative size of the dorsal ovaria increases rapidly as the specimens grow bigger. The specimen figured by ÖPIK (1934, textfig. 18) represents the maximal stage of development in a highly gerontic specimen. In ordinary ones, the ventral ovaria are considerably larger than the dorsal ones.

Fig. 10. *The vascular system of some Orthids, Atrypids, Rhynchonellids and Porambonitids.* A. *Oligomys exporrecta*, Middle Cambrian, Sweden. From WALCOTT 1912, pl. 88, fig. 1k. Dorsal Valve. B. *Orthostrophia strophomenoides*, dorsal valve. From HALL & CLARKE 1892 pl. 6, fig. 34. C. *Hesperorthis tricenaria* (CONR.) dorsal valve. From HALL & CLARKE 1892, pl. 5, fig. 14. D. «*Dalmanella*» *rankini* REED, dorsal valve. From REED 1917, pl. 9, fig. 32. E. *Retrorsistria retrorsa*, ventral valve. From HALL & CLARKE 1892, pl. 5A, fig. 14. F. *Plaesiomys subquadrata* ventral valve. From HALL & CLARKE 1892, pl. 5A, fig. 17. G. *Levenea subcarinata*. Ventral valve. From HALL & CLARKE 1892, pl. 5C, fig. 32. H. *Schizophoria impressa*, dorsal valve. From HALL & CLARKE 1892, pl. 6A, fig. 27. I. *Schizophoria striatula*, dorsal valve. From DAVIDSON 1853, pl. 7, fig. 133. J. *Atrypa reticularis*, ventral valve. From DAVIDSON 1853, pl. 7, fig. 90. K. «*Rhynchonella*» *acuminata* MARTIN, ventral valve. From DAVIDSON 1853, textfig. 34. L, O. *Camarophoria multiplicata*, dorsal and ventral valve. From DAVIDSON 1853, textfig. 35—36. M. *Porambonites riberoi* SHARPE. From DAVIDSON 1853, pl. 7, fig. 125. N. *Porambonites* sp. from zone 4b*γ*, Billingstad, Asker District. The ovarian (?) impressions are black in fig. C, and dotted in figs. B, D. E. F, I and K.

Compared to the Clitambonitids, the Orthid vascular systems represent a longer range in development, from really polypalmate vascula which directly reflect the external sculpture, to highly differentiated types with five ovaria of two different types. As mentioned above, the Clitambonitids did not develop ovaria which impressed themselves into the calcareous tissue of the valves. The Orthids differ both from the Clitambonitids and the recent Terebratulids (textfig. 8) and Rhynchonellids in having different numbers of vascula in the dorsal and ventral valves.

Strophomenida. (Textfigs. 11, 12). In the Strophomenacea there are also several types of vascular systems. In the Strophomenacea, the vascular system is fairly uniform, and quite resembles that of the highly developed orthids, as it has two large ovaria in the ventral valve, and two slightly smaller ones, and vascula media in the dorsal one. The size and shape of the ovaria vary considerably. Generally large flat-valved species have comparatively small ovaria, and consequently have long terminal branches. In geniculated species, such as *Leptaena* (textfig. 12D—G), the ovaria cover the whole disc, and terminal vascula are confined to the geniculated fringe. In several species the median branches of the vascular arches are not impressed, so that it looks as if there only was one large ovarium. In gerontic specimens there are always median branches.

It is difficult to trace a development in the vascular system of the Strophomenids. Even the oldest ones (*Oslomena osloensis*, *Oepikina* of the *dorsata* group) seem to have large ovaria, and only short terminal branches. The oldest Strophomenids generally have thin shells, and the vascular systems are not known in detail. An exception from the rule is *Kjerulfina* which has very strong median vascula, and where neither ovaria nor other vascula have left any impressions in case they did exist. In fact, apart from having a pedicule foramen and simple teeth, the ventral interior of *Kjerulfina* very much resembles that in *Paleostrophomena.*

As far as can be judged from the material dealt with in this paper, there is no difference between the vascular system of the Strophomenidae, and that of the Stropheodontidae. The younger families have not been studied. The family Christianidae, however, has quite a different vascular system, with three pairs of vascula. Two of them go from the ventral muscle impressions to the posterior margin and are parallel to a thin intervascular septum which lies between them. They give off a number of branches near the margin. The third pair has with certainty only been seen in a few, gerontic specimens. It is short and broad, and gives off a large number of branches towards the sides of the valve. Because of the width of these vascula, they might be believed to contain ovaria, but there is no proof of this. The width might easily be due to the large number of lateral branches. This type of vascular system is similar to that found in many Plectambonitids, and the fact that it is found in the Christianidae, is one of the arguments for referring that family to the Plectambonitacea. The dorsal vascular system of *Christiania* is unknown.

In contrast to the Strophomenacea, the Plectambonitacea show considerable variation as to types of vascular systems. In the Plectambonitacea, too, the ventral vascular systems are the best known. The material of the dorsal vascula is much smaller than that of the ventral ones. (Text fig. 11.)

A common type is that found in *Paleostrophomena*, *Grorudia*, *Ptychoglyptus* and possibly *Inversella* and other genera. In this, the ventral vascula consist of two ovarial impressions placed near the hinge-line, from which two bundles of vacula spread to all the margins of the valve. The vascula are often fairly broad, even if their proximal ends always are thin. The ovarian impressions can scarcely be distinguished from the inner surface of the valve and from the vascula. They are also considerably larger in more highly developed species of *Paleostrophomena* than in the probably more primitive *Grorudia*.

In most other Plectambonitids, there are three pairs of vascula. However, it is a characteristic feature that one pair is dominant, the other, smaller ones, are easily overlooked since they are only found in gerontic specimens. One very rarely finds three pairs of vascula of about the same strength as for instance in *Diambonia anatoli* (textfig. 11R). In *Sowerbyella* and a number of related genera, and in *Leptelloidea*, the vascula spondylaria are strongly developed (textfig. 11H). There are only a few specimens where the median vascula appear as two thin strings along the median line of the specimens. The vascula dentalia are developed as more or less triangular ovarian impressions with a fringe of thin vascular branches (textfigs. 11I).

In *Leptelloidea leptelloides*, the vascula spondylaria are weakly developed and one can only see the ovaria with their fringe of vascula

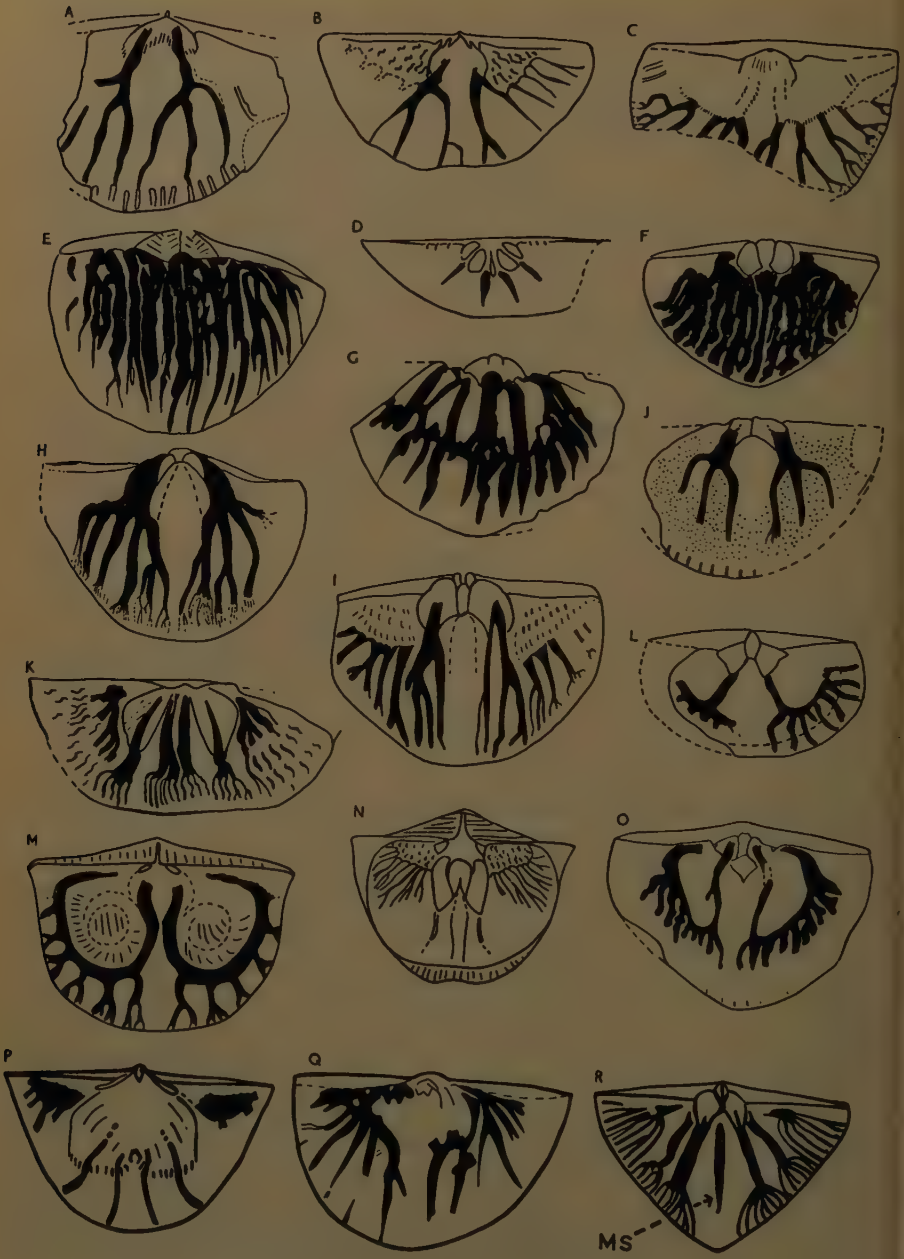

Fig. 11.

(judging from Öpik 1930, textfig. 14). *Leptestia* apparently had vascular arches and it is unknown whether they developed from the vascular system found in the other Plentambonitacea.

In *Sampo* and *Leptellina* the vascula dentalia are strongly developed, and the other vascula are considerably less so. In *Leptellina* they form arches, reaching almost to the median line of the valve. The vascula are broad and irregular in shape, and this indicates that they contained the ovaria. The vascula spondylaria, which only are found in gerontic specimens, are very thin, and in some cases they seem to be united with the vascula dentalia. There is no sign of the

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Fig. 11. *Vascular system of the Plectambonitacea.* A. *Grorudia* (?) *glabrata* sp. n. ventral valve. Zone 4ba, Oslo district. cf. pl. 1 fig. 12. B. *Paleostrophomena concava* Schmidt, ventral valve. Kukruse Stage, Esthonia. From Öpik 1933, pl. 2, fig. 2. C. *Ptychoglyptus valdari* sp. n. ventral valve. Zone 4ba, Billingstad, Asker district. cf. pl. 1, fig. 1. D. *Grorudia grorudi* sp. n. dorsal valve. Zone 4aβ, Tåsen, Oslo district, cf. pl. 1, fig. 10. E—F *Sampo indentata*, two ventral valves. F. is tilted to show the marginal vasculae. Zone 4bγ, Hvalstad, Asker district. cf. pl. 4, fig. 8. G. *Sampo indentata* ventral valve with less strongly developed vascular impressions. Zone 4bγ (lowest part), Hvalstad, Asker district. H. *Sowerbyella millinensis* Jones, ventral valve, SM, A40662, Gas Works, Llandovery, Haverfordwest, Pembrokshire. I. *Sowerbyella ringsakerensis.* ventral valve. From lower part of the Coelosphaeridium zone, Ringsaker district. (cf. pl. 6, fig. 4) J. *Sowerbyella sericea askerensis* (Sow.) ventral valve, zone 4bγ, Hvalstad, Asker district. K. *Sowerbyella* cf. *rhombica conspicua* (Reed) dorsal valve. SM. A40671. Upper Bala, Gelli Grin, Bala, Merionetshire. L. *Leptelloidea llandelioensis* (Dav) ventral valve, Balclatchie Group, Ardmillan, Girvan district, Scotland. (From Reed 1917, pl. 13, fig. 34). M. *Leptestia jukesi*. Ventral valve. (From Hall & Clarke 1892, textfigs. 19—20). N. *Leptelloidea leptelloides* (Bekker). Kukruse Stage, Esthonia, Ventral valve. From Öpik 1930, textfig. 14. O. *Sampo* (L.) *oepiki* ventral valve, PMO 57733, zone 4ba—β, Hadeland district. (cf. pl. 4, fig. 6). P. *Sampo indentata* sp. n. dorsal valve, zone 4bγ, Hvalstad, Asker district. (cf. pl. 2, fig. 15). Q. *Leptelloidea* sp. ventral valve, SM, A40669a. Basal Ashgillian, Pen-y-garnedd, 4 miles S.E. of Llanfyllin, Montgomeryshire. R. *Diambonia anatoli* sp. n. ventral valve. Zone 4ba, Nesøya, Asker district. (MS = median septum).

The figures are drawn from casts, except B, M and N which are from valves, and D, K and P which are drawn from latex impressions of casts.

The magnification is variable. Ovarian (?) impressions are striated in figs. B, I and N, and black in fig. P.

Numbers starting with SM, A... indicate that the specimen belong to Sedgwick Museum, Cambridge.

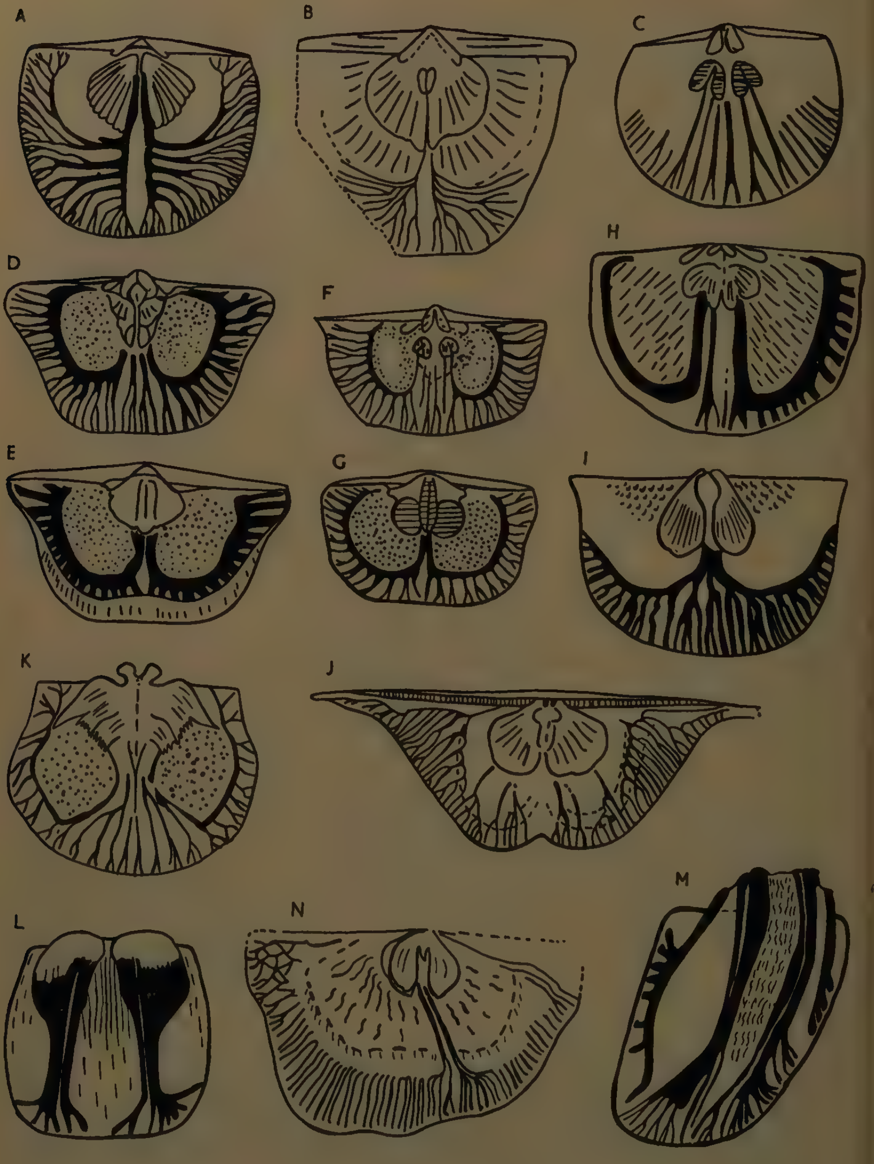

Fig. 12.

vascula media. In *Sampo*, the greater part of the interior of the ventral valve is filled with broad anastomosing vascula. Because of the large number of branches and the numerous anastomoses, it is difficult to see which vascula are developed. In *S. indentata*, the vascula dentalia seem to be dominant, but there are also vascula spondylaria, although they are not as strong as the vascula dentalia. The anastomoses seem to start as a concentric ring about half-way to the margin (textfig. 11 C). In younger species (*S. hiiuensis* and *S. ruralis*) the vascula spondylaria are strongly developed. The majority of the branches of these species also appear to belong to vascula dentalia. Because of the complicated net of vascula, one cannot be absolutely certain that there were no vascula media.

In the dorsal valve of the Plectambonitacea, the variations in the vascular system are not as great as in the ventral. Generally all three pairs of vascula are present. In some species the vascula cruralia have small triangular ovaria, as for instance *Sampo indentata*. In this species there is a marked difference between the broad, frequently branching and anastomosing vascula in the ventral valve, and the thin, unbranched vascula in the dorsal. It is also worth noting that the vascula media and the vascula myaria continue through the branchial lamellae in narrow furrows. In other species where there are two branchial lamellae, as for instance in *Sowerbyella*, the vascula media are placed between the lamellae, and the vascula myaria cut

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Fig. 12. *Vascular system of the Strophomenacea.* A. *Strophomena expansa*, ventral valve. From DAVIDSON 1853, pl. 8, fig. 162. B. *Strophomena filitexta*, ventral valve. From HALL & CLARKE 1892, pl. 9A, fig. 15, C. *Rafinesquina alternata* (?) dorsal valve. From DAVIDSON 1853, pl. 8, fig. 160. D—E. *Leptaena analoga* PHILLIPS, ventral and dorsal valves. From DAVIDSON 1861, pl. 28, fig. 10, 9. F—G. *Leptaena depressa* SOW. ventral and dorsal valves. From DAVIDSON 1853, pl. 8, figs. 171, 170. H. *Strophomena filitexta* HALL, dorsal valve. From HALL & CLARKE 1892, pl. 9A, fig. 10. I. *Douvillina inaequistriata*, ventral valve. from HALL & CLARKE 1892, pl. 14, fig. 13. J. *Strophonelloides caelata*, dorsal valve. From HALL & CLARKE 1892, pl. 15A, fig. 10. K. *Oepikina dorsata* (BEKKER). Dorsal valve. Kukruse Stage. Esthonia. From ÖPIK 1930, textfig. 22. L. *Christiania holtedahli* sp. n. ventral valve, zone 4ba, Billingstad, Asker district. M. *Christiania* sp., ventral valve Geol. Surv. 10913, Ashgillian Cynwyd, Wales. N. *Leptaena* sp. ventral valve. From zone 8c, (Wenlock) Malmøya, Oslo district. The figures L. M and N are drawn from casts, the rest from valves. The specimen in fig. M belongs to the Geological Survey and Museum, London.

through them, dividing them into two subequal parts. Even in specimens where the dorsal vascula are not developed, this diagonal groove is found in the branchial lamellae (cf. pl. 3 fig. 4). Also in *Sowerbyella*, ovaria-like areas are formed by the vascula cruralia near the hingeline.

Conclusion: The taxonomic importance of the vascular system has been stressed by several authors. The fact that completely develloped, characteristic vascular systems only are found in a few old adult specimens, reduces the diagnostic value of this feature. In some groups, the vascular system proves to be very useful, as for instance in the Clitambonacea, where the families Estlandidae and Clitambonitidae have different vascular systems. This difference corresponds to a just as important difference in shell-structure and spondylium.

The vascular system of the Orthids is highly variable, and it is probable that further studies will show that it is of considerable taxonomic value. It is, however, outside the scoope of this paper to deal with this in detail.

In the Strophomenacea, the vascula are too uniformly developed to be of much taxonomic importance.

The Plectambonitacea can easily be divided according to the vascular system and the various groups seem to be identical with systematic units based on other features. The author made extensive use of the ventral vascular system in this group as a taxonomic guide, because this feature seems less variable as to external influences than most features used in the taxonomy of this group. One reason for placing the family Christianidae in the Plectambonitacea is the resemblance as to vascular systems.

The study of the vascular system of the palaeozoic braciopods is still in its early stages, but through further studies and patient collecting it might give a more natural classification than many other features.

THE MUSCULAR SYSTEM

The muscular system of the Strophomenids is known to consist of adductors and diductors. All the muscles were obliquely conical. The small attachments of the adductor muscles are in the ventral valve, and the larger ones in the dorsal valve. The diductors have their

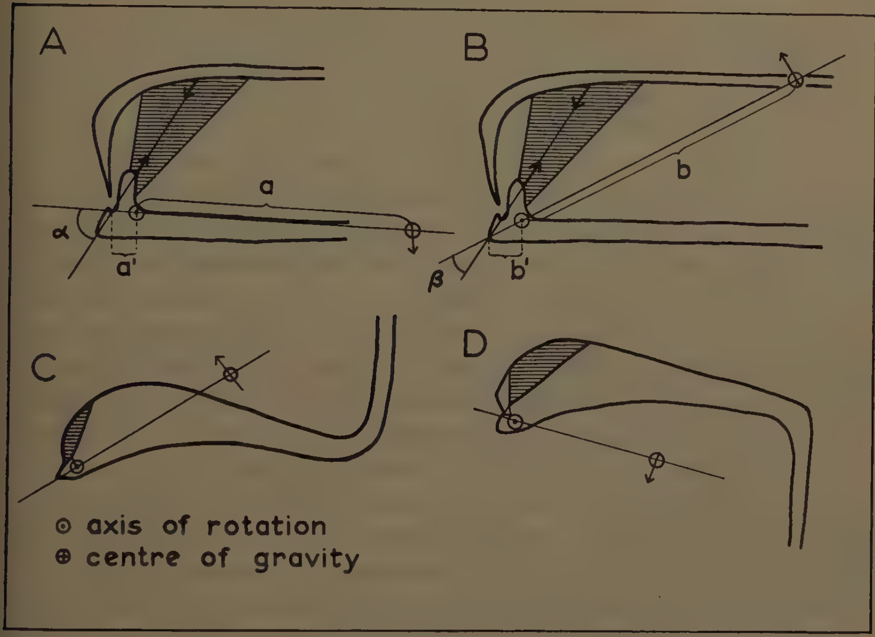

Fig. 13. Illustrating the structure of the muscle system of the Strophomenidae. For explanation, see the text.

small attachments on the cardinal processes, and the larger ones in the ventral valve. In some instances the larger muscle impressions are bilobed, indicating that the muscles were paired. In all other cases there are only two adductors and two diductors.

The mechanism of the adductor muscles is quite simple, and it is not necessary to describe it here. That of the diductors, which work according to the lever principle is more complicated. The force necessary to open the valves of a specimen resting on the ventral one, is:

$$K = \sin.\,\alpha g \frac{a'}{a} \qquad (1)$$

where K is the force, α the angle between the plane of rotation and the direction of the diductor muscles, and a' is the distance between the axis of rotation and the centre of gravity. a is the projection of the distance between the axis of rotation and the muscle attachments on the cardinal processes. g is the weight of the valve (see textfig. 13).

The corresponding equation for a specimen resting on the dorsal valve, is

$$K' = \sin. \beta g' \frac{b'}{b} \qquad (2)$$

The effect of the diductor muscles is therefore a function of the angle a (or β), which should approach 90° to make the muscle effective. These angles in their turn are dependent on the position of the centre of gravity of the valves. Since the position of this point will change as the valve grows, the angles a and β will change correspondingly, if the muscle impressions are unaltered. A number of species have shown that the shape and size of the ventral muscle impressions change during the growth of the individual, and this is obviously a consequence of the mechanisms described here.

The change in the position of the centre of gravity will be especially prominent in species with geniculated valves. In many of these the centre of gravty lies outside the valves. Textfig. 13 shows diagramatically the change in shape and position of the ventral, muscle impressions in flat specimens, dorsally geniculated and ventrally geniculated ones. It appears that dorsally geniculated specimens will have longer muscle impressions than those which are ventrally geniculated, if the valves have the same shape and weight.

The general convexity of the valves also has an influence on the shape of the muscles. Strongly convex specimens generally have broad, flabellate muscles, while flat or geniculated ones have more elongate muscles.

It is interesting to note that there is an intimate connection between the convexity of the valve, and the muscle attachments. Generally the convexity of the valves is not regarded as being a feature of great systematic importance. The author's studies have, however, led to the conclusion that the umbonal convexity is intimately connected with the development of the muscles, and must be considered as a stable feature in most species. The convexity of the central and marginal parts of the valves seem to be much more variable, and can not be correlated with internal features.

Furthermore the umbonal part was the first one to be developed and it seems reasonable that the features found in this region were less subject to fenotypical variations than the marginal parts of the valve.

In specimens with strong umbonal convexity, the angle α (or β) is large and the muscle impressions smaller, while in specimens with flatter umbo, the muscles are attached further behind, and the angle α (or β) is smaller (cf. textfig. 13). Generally this results in larger muscle impressions.

Regarding the geniculation, at least some species (or genera) seem to have a great plasticity, and the change in shape of the muscle impressions due to the geniculation (cf. textfig. 13 C-D), are probably only mechanical adjustments which are not of any great systematical significance.

The muscular system of *Oepikina* and related genera is slightly different. Here the dorsal adductor muscle impressions seem to be replaced by septa. No special impressions of the adductor muscles are visible in ordinary specimens. In some especially well preserved interiors from the Kukruse Stage in Esthonia, the muscle impressions appear as dark, semitranslucent spots contrasting against the white, opaque substance of the rest of the valve. In dorsal interiors of this type, there are muscle attachments both in front of the lateral septa (textfig. 28A), and between the median and lateral septa. The latter are the smallest. All impressions are of irregular shape, indicating that the muscles consisted of a bundle of fibres. The edges of the septa are also translucent, but that might be due to the fact that the branchiae were attached to them.

Double dorsal adductor muscles are found in several primitive species (*Oslomena* spp. and *Kiaeromena juvenilis*). In *Kiaeromena kjerulfi*, too, there is a pair of small posterocentral impressions (pl. 10 fig. 2). Generally, all Strophomenacea have only one pair of dorsal adductors. In the transitional species mentioned above, the formation of visible impressions of these muscles is connected with the loss of branchial septa (pl. 12 fig. 12, pl. 7 fig. 17). Because of the small material available, it is impossible to know definitely if the septa had some connection with the muscles, or if the correlation in development was accidental.

From equation (1) it is obvious that a' and a must be on opposite sides of the axis of rotation (= the line through the apex of the teeth). If not, the diductors will act in the opposite direction, as adductors. In several species, the muscle attachments on the cardial processes is on the same side as the centre of gravity, but the distance a' is still positive, because the cardinal processes are high, or the angle α is comparatively small (textfig. 13).

The forces necessary to open the valve, is a function of the balance 'a/a in (1). In most specimens this value is about 1/5—1/7. In other species, especially among the Rafinesquinas, it is as low as 1/20 or even less. In these cases, the diductor muscles alone could scarcely have opened the valves.

The presence of a strong pseudodeltidium and a chilidial plate in many specimens without functional diductors or very high a'/a seems to indicate that these species had a ligament uniting the pseudodeltidium and the chilidium, which served to open the valves. In many species the diductor, at least partially, took over at a later stage of growth. The structure of the pseudodeltidium, described above, seems to give support of this theory. It is also worth noting that most species with strong cardinal processes and diductor impression do not have a well developed pseudodeltidium or chilidium. This negative correlation between the development of the cardinal processes and the pseudodeltidium is found in many groups within the Strophomenacea, as for instance the Stropheodontidae, where the development of the cardinal processes in the direction of higher efficiency can be directly correlated with the gradual loss of the pseudodeltidium and chilidium (cf. WILLIAMS 1953a, textfigs. 2—3). In *Strophomena norvegica* and *Kiaeromena kjerulfi*, both the cardinal processes and the pseudodeltidia are strongly developed. In the first mentioned species, the growth lines are much less prominant than in the pseudodeltidia of most species. The fact that the cardinal processes project over the chilidium, and the pseudodeltidium is sharply angular, indicates that no ligament was developed in this species. In *Kiaeromena kjerulfi*, both the pseudodeltidium, the chilidium and the diductor muscles were strongly developed. This is probably due to the fact that the valves of this species are extremely heavy so that both muscles and ligament were needed to open them. The ratio a'/a is also very large in this species.

In *Oslomena* and *Oepikina* also a negative correlation is found between the development of the pseudodeltidium and the cardinal processes and the diductor impressions. In *Oslomena* the diductors are comparatively small (cf. textfig. 34 D—E), and the cardinal processes are not fully developed either. The pseudodeltidium (described above) is very strong, with prominent growth lamellae. This species has no real chilidal plate, but the callosity on which the cardinal processes are placed, have strong growth lemellae, corresponding to those of the pseudodeltidium. The cardinal processes of *Oepikina* are among the largest to be found in the brachiopoda, and the ventral diductor impressions are very big, filling most of the ventral interior (cf. textfig. 34 A). The pseudodeltidium is small and smooth, and the chilidium is scarcely developed.

The muscles of the Plectambonitacea are not by far as well known as those of the Strophomenacea. Generally the muscle impressions do not seem to be well defined from the rest of the valve in many Plectambonitacea. There are several types of muscular systems, and they are found in most stages of development or differentiation of the impressions.

In some of the Leptestinids, the muscular system of the ventral valve is similar to that of the Strophomenacea, with one large double impression (diductors?) and a small, generally double one in the middle of the large one (adductor?). All the muscles are placed near the hinge line in the often very convex specimens. In the dorsal valve, the muscle impressions are seldom developed. The adductor muscles might have been attached to the branchial lamellae, or to the «x-plate» (cf. ÖPIK 1933).

In *Paleostrophomena* and some other genera, even the ventral muscles have left no impressions. There is a striking resemblance between the ventral interior of some of these species and young or primitive Strophomenids, and it is most probable that they did have muscles, but that these for some reason did not leave impressions on the valve. (Compare *Grorudia* (?) *glabrata*, Pl. 1 fig. 12 to *Leptaena ennessbe*, Pl. 10 fig. 9). The cardinal process of the Plectambonitacea varies considerably. Generally it is triple, but sometimes bifid, simple or quintuple, or absent altogether. This indicates that the diductors were more variable than in the Strophomenacea. The distance a' is generally very small. This is partly compensated by the strong convexity of many species, which makes the distance a correspondingly shorter.

In *Sowerbyella* and related genera, the ventral diductor muscles are to a great extent filled with the impressions of the vascula, so that there might be some doubt as to whether they are muscle im-

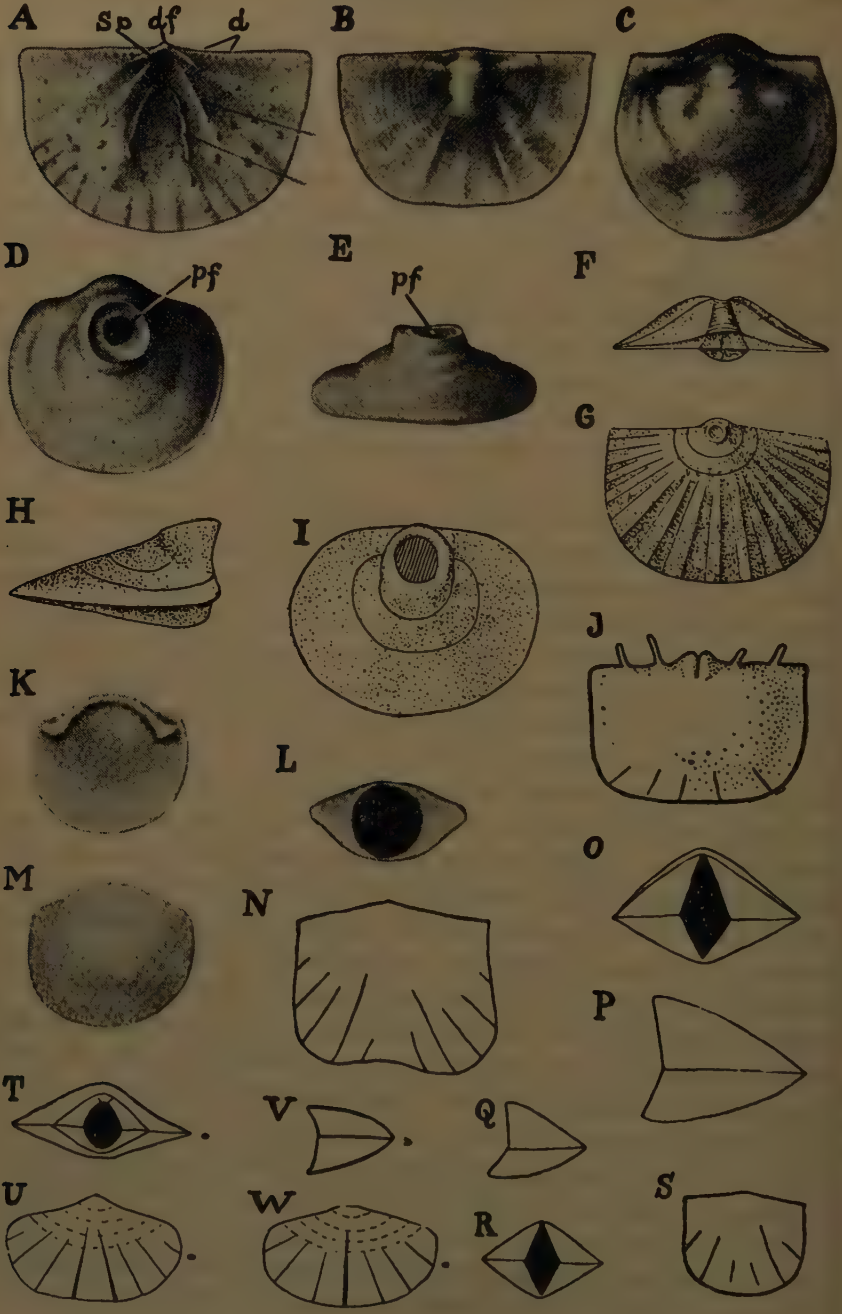

Fig. 14.

pressions at all. The impressions are large, elongate diverging at about 90°, and continue gradually into the vascula. In old, well calcified specimens, the vascular impressions continue almost to the hinge line. The adductor impressions reported from the Sowerbyellinids (cf. ÖPIK 1930, 1933), have an interesting structure. They consist of two conical cavities reaching almost to the exterior of the valve (text-fig. 23). These ventral cavities, which can clearly be seen in casts, is a characteristic feature of the Sowerbyellinae, and it is not found in adult specimens outside that family. Generally, the laminated tissue in the muscle impressions grew in thickness together with the rest of the valve, but in the case of the ventral cavities, the muscles seem to have been attached to the interior surface of the external layer of the valve during the growth of the animal.

GROWTH AND ONTOGENY

The ontogeny of the palaeozoic brachiopods has been described especially by BEECHER (1891, 1891a, 1892, BEECHER & CLARKE 1889). More recently KOZLOWSKI (1929), ARBER (1940), IVANOVA (1949), SARYTSCHEVA (1948), and others have published papers on this subject.

These papers show that there are two widely different types of ontogenetic development in the «Protrematous» brachiopods. In the Orthacea, the larvae had high areas, open delthyrium and notothy-

Fig. 14. Larval valves of brachiopods. A—B. *Plectodonta mariae* KOZLOWSKI 1929, Interior and exterior of a dorsal valve. 30x. from KOZLOWSKI 1929, fig. 36, B—C, p. 116. *C—D—E. Leptaena emarginata* (BARRANDE), *C.* exterior of dorsal valve, D—E. two different views of the exterior of the ventral valve. From KOZLOWSKI 1929, textfig. 25, p. 93. F—G—H—I. *Leptaena «rhomboidalis»* F—G a relatively large larval form seen from the areas, and from the ventral side. H—I a small larval form seen from the side, and from the ventral valve. From BEECHER 1891. J. *Chonetes* (*Chonetes*) *carboniferus* KEYSERLING, the cast of a larval ventral valve, showing double ventral cavities. 16x. From SOKOLSKAJA 1950, textfig. 20, p. 56. K—L—M *Enteletes lamarckii* (FISCHER) Ventral exterior and interior, and a complete specimen seen from the area. 35x. From IVANOVA 1949, textfig. 1, 1 a—c, p. 245. N—O—P—Q—R—S. *Dicoelosia biloba* (L.) Two specimens, seen from the side, the ventral valve, and the areas. Note the angular pedicle foramen. From BEECHER 1892, pl. 1. T—U—V—W. *Platystrophia* sp. Dorsal, areal and side of two specimens. From CUMMINGS 1903.

rium with no chilidium or deltidium. The pedicle probably was thick and placed between both valves, filling both the delthyrium and the nothothyrium. This type of larval development is found in a large number of species belonging to different genera, ranging from Ordovician to Permian. The difference between the species and genera is small, they vary as to the details of the sculpture and in the outline of the pedicle foramen, which is rhomb-shaped in most forms, and rounded, circular or oval in others. (Textfig. 14).

In the Strophomenidae, the larvae are quite different. Both valves are smooth, and the ventral one has a very dominant pedicle-tube, which is subcentral in the youngest larva, and more peripheric in the older one. There is no foramen in the dorsal valve. This type of structure is found in *Leptaena*, and some other genera.

The material studied by the author includes fairly complete ontogentic series of three species from the Middle Ordovician of the Oslo Region, *Kjerulfina foliovalve* (p. 155), *Christiania holtedahli* (p. 117) and *Sowerbyella sericea soudleyensis* (p. 91). In addition the author has studied a number of larval valves of *Parmorthis elegantula* and *Leptaena depressa* from the Silurian of Gotland. The study of the last mentioned specimens, however, only confirmed the results of the previous authors, and they are therefore not considered further. The larval valves of *Sowerbyella sericea soudleyensis* do not provide any additional material on the development of the species. Even the smallest larvae are surprisingly like the adults. (Pl. 3 figs. 1—4).

A ventral pedicle foramen in the Sowerbyellinids is reported by ARBER (1940) and KOZLOWSKI (1929). The author has studied a large number of well preserved specimens of Sowerbyellinids, but none of them had a ventral foramen. Many slightly worn specimens, however, show one or both the ventral pits, probably the deep attachments for the adductor muscles. These almost reach to the exterior surface of the valves, and in semi-translucent specimens they can often be seen when the valves are worn. The pedicle foramen described by the authors mentioned above, might be pits from such specimens. They can be distinguished from the pedicle foramen in that there are two of them, and in not being placed centrally but slightly to the side.

The fact that *Christiania oblonga*, which has a ventral pedicle foramen, has a cardinal process similar to that of the Sowerbyellinids, could indicate that there are two different foramina, a dorsal and a ventral which seem to occur alternatively. If the pedicle had moved from the dorsal to the ventral valve, that would evidently have caused some modifications to the cardinal processes.

The final proof of the presence of both foramina is the fact that they are both found in *Oepikina dorsata* (textfig. 2, pl. 14, fig. 7). In that species, the cardinal processes correspond to the lateral branches of the cardinal process in *Sowerbyella*, and the median branch, which is the largest one in *Sowerbyella*, is reduced to a very low, thin septum between the two very large, forked processes.

The dorsal foramen was called the notothyrial cavity by earlier authors (i. a. WILLIAMS 1953). It differs from the pedicle foramen, which is cylindrical, in being conical. In at least *Alwynella* and *Eoplectodonta acuminata*, it is definitely a real perforation in the calcareous shell. It can be seen both in thin sections, and as an external opening. In *Sowerbyella sericea* (subsp. div.) the internal opening is very broad, while the external one is extremely small, if present at all. Structures similar to the dorsal foramen are also found of the Sowerbyellinae, but here they only appear as traces. At the base outside the cardinal processes in *Leptaena depressa*, there is a whirl in the growth laminae which might be an atrophied foramen. The foramen found in *Oepikina* is mentioned above.

Because of the conical shape, it is improbable that the dorsal foramen was a pedicle one. The fact that it mainly is found in the Sowerbyellinae, indicates another possibility. In this subfamily the ventral adductor muscles are deep, conical and almost reach right through the valve. It is therefore possible that the dorsal foramen is the impression of a muscle or another organ, which was attached to the exterior side of the cardinal process, or to the periostracum. To the author's knowledge, no such muscles are known from recent brachiopods. The interpretation of the dorsal foramen must therefore be highly provisional.

In the larval valves of a number of Strophomenids, there is a distinct dorsal cavity (cf. *Christiania holtedahli*, textfig. 30 A—F, pl. 5 figs. 2, 5, 8, *Plectodonta mariae*, textfig. 14 A—B), which, at least in *Christiania* terminates in a foramen. This grove which probably has nothing to do with the dorsal foramen in Sowerbyellinids, is cylindrical, and has the same diameter as the pedicle foramen, which is constant during growth in this species (*C. holtedahli*). This grove may therefore be the pedicle foramen. It is not bridged by the chilidal plates (= socket plates), and the ontogenetic development shows that the pedicle gradually is transferred to the ventral valve. In *Oepikina*, which both had a pedicle and a dorsal foramen, the trifid cardinal process with its foramen was probably formed after the pedicle was transferred to the ventral valve.

This dorsal grove is found also in a number of Middle Ordovician Strophomenidae, and it is therefore not restricted to the Plectambonitacea. The material of larval ventral valves is rather small, but not a single specimen similar to *Leptaena* (with large pedicle tube) is found. Judging from the direction of the hemicylindrical pedicle groove in the dorsal valve, the pedicle opening must in some cases have been completely in the that valve.

It is very difficult to explain these contradictory observations. A possibility is that the mantle was reversed during the larval development, such as in the Terebratulida (cf. PERCIVAL 1944), and that this reversion took place later in the development in the older species than in the Silurian and Devonian Leptaenas studied by the earlier authors.

At present, there are, however, no definite proofs for this hypotesis.

It is obvious that both the ontogeny and the presence of a dorsal foramen is of considerable systematical value. The fact that the ontogeny only is known from comparatively few species, and it is unknown, or almost unknown, in large groups make the use of these features difficult. No larvae are known from such important groups as the older Plectambonitida and the *Kjaerina-Rafinesquina-Stropheodonta* lineage, and it is therefore too early to split the groups according to the ontogeny. However, it would seem natural to divide the Plectambonitacea into two groups, one consisting of the older forms, Taffinidae and Plectambonitidae, and the other including Christianidae, Chonetidae, and Sowerbyellidae.

As mentioned below (Trends of evolution in the Strophomenidae), the Strophomenids might also be divided into two main groups, based on the structure of the cardinalia. Since both the ontogeny and the detailed histological structure of the majority of the Strophomenids are unknown, one cannot draw any conclusions from the fragmentary material available.

GROWTH: Detailed studies have been made of variations both in size and growth. For this purpose extensive material is required, and this has limited the study to a few species only. It is also difficult to find a sufficient number of specimens for studying each population statistically. Strict mathematic methods have therefore not been applied. A large percentage of the specimens are distorted, due to growth anomalies or tectonic pressure. This decreases the number of specimens on which measurements can be made even further, and may possibly introduce a bias.

The studies were concentrated on the variations within one population, within a set of contemporaneous, or at least nearly contemporaneous populations, and populations of different age, all of the same species.

The number of species was very small, the only ones in which all variations were studied were *Christiania holtedahli* and *Oslomena osloensis.*

Generally the variations within one population were small. In a few cases there was considerable variation (the exterior of *Kjerulfina foliovalve*, and the ventral muscle impressions of *Oslomena osloensis*). In some populations there was an amazingly great number of abnormal specimens, generally thin-shelled Strophomenids with healed fractures.

The study of contemporaneous populations showed that the mean size and the proportions are very variable. The variations could generally be correlated with the average size of the other species in the fauna. In *Oslomena osloensis* for instance, the typical form is found together with other species of moderate size. In some localities in the Oslo—Asker district, a smaller form occurs, together with the same fauna, the species being on a smaller scale. In this case, too, the proportions vary and the smaller specimens are slightly broader than the typical form. In the Oslo—Asker district the geographical distribution of the types is very complicated. In most localities there is only one type, while in a few one can find some intermediate forms. Both types are never found together. In the Ringerike district the species, in this case slightly larger than the typical forms, is found together with large, thin-shelled species. The difference in size, however, is small (see textfig. 37). In the Mjøsa districts (Toten and Ringsaker), the specimens are considerably larger than the typical form.

They occur together with other specimens, which also are much larger than those found in the Oslo—Asker district.

A similar variation is found in *Christiania holtedahli*, and to a smaller extent also in *Chonetoidea gamma*. In other species, such as *Eoplectodonta acuminata*, the size hardly varies at all, even in localities were the other species show considerable variation. In *Ptychoglyptus valdari* the species vary, and in the population where the largest specimens are found, there are also specimens which are dorsally geniculated. This is not found in the otherwise smaller populations. Possibly the geniculation only took place when the disc had grown to a certain size, which was not reached in the other populations.

Probably all the varieties described above should be regarded as being ecological variations only, and do not merit subspecific rank. In many cases it is of course difficult to discriminate between closely related, genotypically different forms, and fenotypical varieties.

A number of populations of *Christiania holtedahli* from different horizons have also been studied. A gradual increase in size has been observed from older to younger populations, and also a change in shape, from specimens with equal width in the oldest population, to specimens which are widest behind in the younger ones. This line of development leads from *Christiania elongata*, and specimens resembling *Christiania oblonga* in zone 4aβ and the lower part of zone 4bα, to the typical specimens of *Christiania holtedahli* in the middle and upper part of zone 4bα. (The vertical and geographical distribution of the *Christiania* species is shown in textfig. 31, p. 121).

The studies of the relative growth-rate have been concentrated on the rate HL/L (Hingeline/greatest length). Measurements were made both of samples of specimens, and of series of growth-lines, in single specimens. Several correlations show that the two methods give identical results (cf. textfig. 35). It has to be mentioned, however, that specimens in which the growth-lines are accentuated by healed fractures can not be used for these studies.

The species studied fall into two main groups, those in which the ratio HL/L is constant during the growth (except in the youngest larval valves), and those in which the ratio change considerably. Representatives of the first group, with isometric growth, is *Sowerbyella sericea soudleyensis* and *Strophomena norvegica* (Textfigs. 22, 35). In species of this group, the growth is isometric and radial,

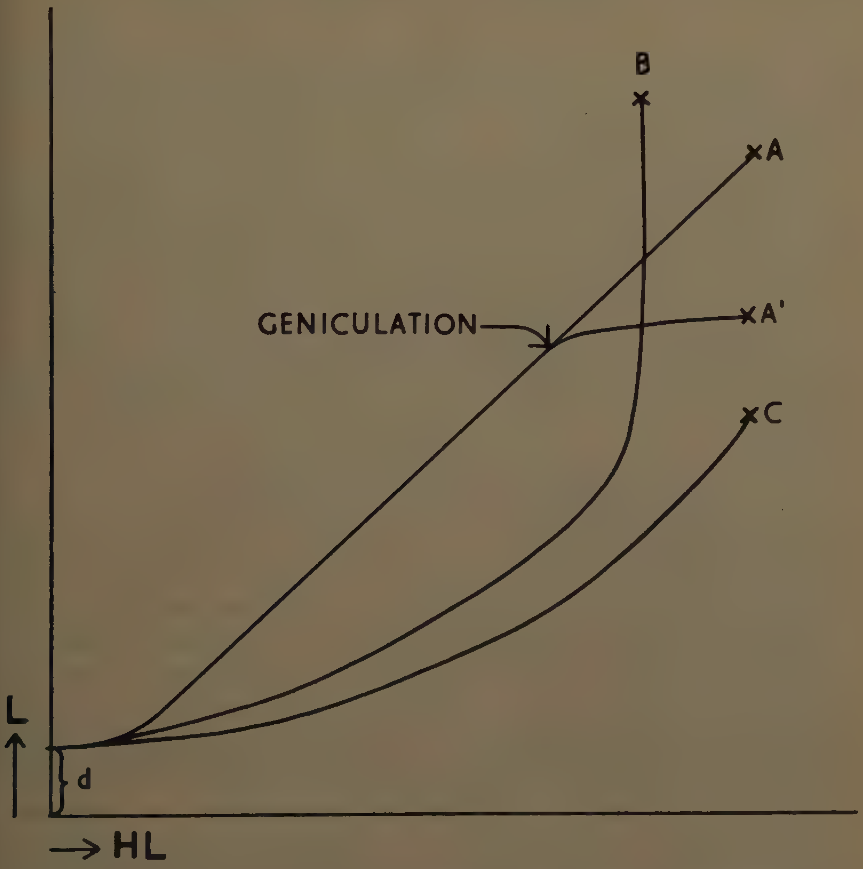

Fig. 15. The development of the Length/Hinge-line ratio in the different types of growth. (See text) A = Isometric growth. A' = Isometric growth and geniculation. B = Christiania-type of allometric growth. C = Alwynella-type of allometric growth. d = Diameter of smallest larval valve.

from a centre at the hinge-line. The ratio HL/L is therefore 2 or more.

The second group, which show allometric growth, might be divided in several subgroups. The first one include the geniculated species. In the early stage of growth, they resemble the species with isometric growth, but at a certain total size, the valves turn abruptly, and the growth continue allometrically. If the angle between the disc and the fringe is 90° or less, the observed length will cease to grow, and if it is between 180° and 90°, the observed addition in length is considerably smaller then the actual growth of the fringe. The hinge-line might or might not continue to grow. In the first case it forms long pointed cardinal angles.

The critical size for the geniculation might be constant for the species, but it is likely that it is different in different populations, at least in some species. In *Ptychoglyptus valdari* (p. 58) only a fraction of the generally small specimens from the Oslo--Asker district reach the size necessary for geniculation. In the Ringerike district where most brachiopod specimens are larger, all the comparatively few specimens known are geniculated. In this species, therefore, the critical size seems to be constant for the species, and independant of the ecology.

The development of the geniculation in the Strophomenids is therefore probably similar to the development of the horns of the titanotheries discussed by HUXLEY (1944). It might be suspected that the possibility of geniculation was present in all Strophomenids, but that the critical size was not reached in a number of species.

A second type of allometric growth is found in *Christiania* (Text-fig. 29) and probably some species of *Oepikina*. Here the hinge-line reaches a maximal size rather early in the development of the specimens, and all the later growth is in the transversal and vertical directions. The maximal width of the hinge-line is different in the different populations, and closely connected with the maximal size of the specimens, so that the HL/L ratio of the adult specimens is constant in all populations, when the absolute size vary.

This constant development gives a certain scale for the relative individual size in the different populations, because when the *Christiania* populations show large specimens, the other brachiopod species will show the same, even if smaller variations occur.

The third type of allometric growth is found in the new genus *Alwynella*. From the study of the growth-lines of a large number of specimens, it appears that the increase in length is more rapid than that of the hingeline. Since the ratio HL/L is rather high in most specimens belonging to this genus, the growth rates must have been opposite to those observed in the early stages of development of the valves. This indicate that the hingeline growed rapidly till the HL/L ratio was 5—6 or even more, and later it decreased slowly till it reached

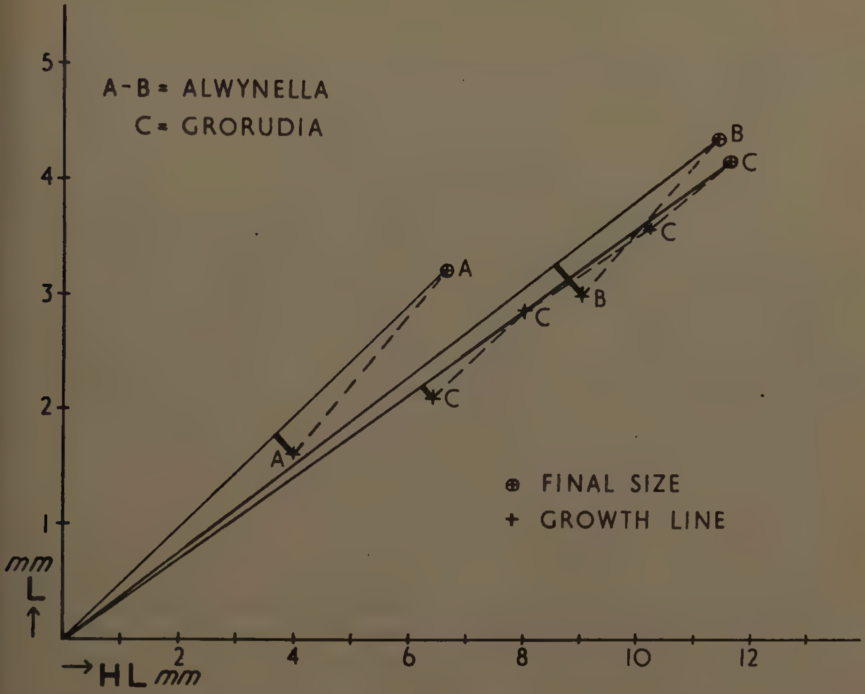

Fig. 16. Diagram showing the correlation between the L/HL index in growth lines and outline in species with allometric growth (A/B) and isometric growth(C).

the value for adult specimens (2,5—3,5). This type of growth may be called elliptical allometric growth, because the directions of growth form an ecclipse with the longest diameter along the hinge-line in the earliest stages, and later with the shortest axis along the hinge-line. (Textfig. 15).

The material of measurements is still much too small to be treated statistically, but it certainly has some significance. It also has some practical value, because this allometric growth is not found in the genus *Grorudia*. Exteriors of *Alwynella* and *Grorudia*, which occur together, and are very similar, might be distinguished by measuring the growth-lines. If the growth is isometric, the valve belong to *Grorudia*, if it is allometric, the valve belong to *Alwynella*. (Cf. Textfig. 16).

The data presented here are at the moment to few, and too fragmentary to allow any important biological conclusions. They are mentioned because further investigations along these lines might give important facts, and because already these small attempts have given some results of practical and diagnostic value.

Description of Fossils.

Suborder Strophomenida ÖPIK 1934 EM. WILLIAMS 1953.

Superfamily Plectambonitacea (JONES 1928) nom. transl. COOPER & WILLIAMS 1952.

Family Sowerbyellidae (ÖPIK 1930) nom. transl. nov.[1]
(= Leptestiidae (ÖPIK 1933), nom. transl. WILLIAMS 1953).

Subfamily Leptestina ÖPIK 1933.

Ptychoglyptus WILLARD 1928.

This genus was originally described as a Rafinesquinid, but later studies have shown that it is a Plectambonitid, probably belonging to the family Sowerbyellidae. In the new species described below, the ventral interior is similar to that of *Paleostrophomena*, whereas the dorsal is quite different from that genus.

Most species of *Ptychoglyptus* are fonded upon the exterior only, and it is possible that some of them are homeomoorphs, with deviating interior.

Ptychoglyptus valdari. sp. n.

Plate 1, figs. 1—3. Textfigs. 17 and 19 K-L.

Type data: The holotype, PMO 18853, is the cast of a dorsal interiorfrom zone 4bα at Slependen, Oslo—Asker district. (Pl. 1, fig. 2).

Material: About 30 exteriors of valves, 4 complete specimens, 3 ventral and 3 dorsal interiors.

Diagnosis: A *Ptychoglyptus* species with thick valves, numerous ribs and variable geniculation.

Description: A specimen of average size is 30 mm wide and 18 mm long. In most specimens the valves are flat, with a very slight

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[1] This family is formed by the union of the two subfamilies Sowerbyellinae ÖPIK 1930 and Leptestiinae ÖPIK 1933, and should therefore, according to the new rules on zoological nomenclature, have the name of the oldest subfamily.

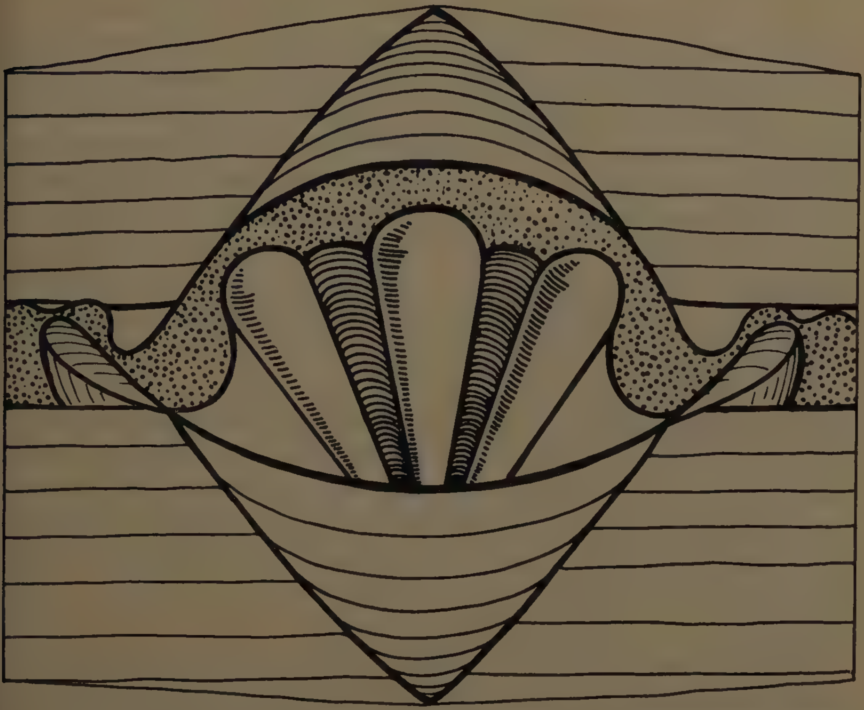


Fig. 17. *Ptychoglyptus valdari* sp. n. Somewhat diagramatic figure showing the median parts of the areas. The valves are separated to show the interior. The drawing is based on a specimen from zone 4bα at Slependen, Asker district.

marginal geniculation, which is opposite in both valves, and in this way provides space for the soft parts of the body. In some specimens the valves are subequally biconvex, and others are dorsally geniculated (cf. p. 54).

The areas are high, triangular, and meet at sharp angles even in young specimens. The pseudodeltidium is comparatively large, and much protruding. A strongly convex chilidium covers the notothyrium (Textfig. 17).

As it is usual in this genus, the sculpture consists of prominent radial ribs which cut the strong concentric rugae. In addition to this, there are fine striae, which in contrast to the ribs, follow the undulations of the rugae. There are 5—8 of them between each rib. In the central part of the valve, and in young specimens, the concentric rugae are continuous, being broken at an angle of less than 180° at each rib. In the rest of the disc, the rugae are not continuous. Each segment between two ribs seems to have developed rugae independant of the other segments. In other specimens the rugae are more continuous, but they are broken sharply so that they form angles pointing posteriorly and anteriorly at every other rib. The differences as to sculpture have not been compared with variations other of features, because all specimens of which the interior of the valves is known have the first mentioned type of sculpture, which is the one usually found. The marginal parts of the valve, which are geniculated, have no concentric rugae. In a few specimens, this nonrugated area include the marginal part of the disc too.

The ventral interior very much resembles that of *Paleostrophomena.* It has a similar vascular system and slightly developed muscle impressions. The teeth are strong, and there is also a pair of small lateral accessory teeth. The accessory teeth themselves have only been observed in one ventral interior, and their existence is mainly proved by the presence of accessory sockets in the three dorsal interiors.

The dorsal interior (Pl. 1, fig. 2) shows small, finely striated branchial lamellae, a large, complex x-plate (cf. Öpik 1933), very strong crural plates which are fused to the chilidium, and a prominent cardinal process consisting of three parts, one central, subcircular and two lateral ones, formed as thick, diverging plates. It grows vertically from the notothyrial platform, and is not supported by septa posteriorly, as for instance in the Sowerbyellinids. The vascular system is unknown, only the marginal vasculae are developed in one specimen.

The shell structure is punctate, no cone-sheets are observed (p. 12, Pl. 13, figs. 6—7). The large ribs of the sculpture are found not only on the surface, as in most species with a thin external layer, but continue as bars down in the tissue of the valve, almost to the inner surface. The interspaces between the ribs are filled with punctate tissue. (Pl. 13, fig. 6).

Remarks: Ptychoglyptus valdari differs from *P. virginensis* Willard 1928 and *P. rugosa* Reed 1932 in the noncontinuity of the concentric rugae, and in having more ribs and thicker valves than the two other species. It appears to be closely related to a species occuring in the Middle Ordovician Lower Reef Limestone in Dalarne, Sweden, which has the same type of sculpture as *P. valdari*, and a more regular convexity, always being flat with sligth opposing geniculation.

A small specimen with *Ptychoglyptus* sculpture is found in zone 4bα at Gåsøya, Oslo—Asker district. There is a sinus in the ventral valve of the specimen, and it might belong to another species. However, the occurence of *P. valdari* in the same layer, and the variable shape of that species, indicates that this deviating specimen belongs to it.

«*Rafinesquina*» *ringerikensis* HOLTEDAHL (1916 p. 30, pl. 3, fig. 7) has a *Ptychoglyptus*-like sculpture, differing from that of *P. valdari*. As the interior of «*R.*» *ringerikensis* is unknown, it is impossible to determine the generic position of that species.

Distribution: Ptychoglyptus valdari is common in the upper part of zone 4bα in the Oslo—Asker district. In the same zone in the Ringerike and Hadeland districts there are some few large specimens belonging to this species.

Genus *Grorudia* gen. nov.

Diagnosis: Leptestiids with paucicostate ornamentation. Ventral interior similar to that of *Paleostrophomena*, with no clearly defined muscle impressions, only two diverging vascular impressions almost from the apex and double teeth. Dorsal interior with strong, bilobed branchial lamella, which are not elevated, triple median septum, and absent or large, flat cardinal process. Hinge-line apparently not denticulated. Shells generally flat, or slightly convex-concave.

Type species: Grorudia grorudi sp. n. from the lower Middle Ordovician (zone 4aβ) of the Oslo Region.

Remarks: Grorudia is probably related to *Paleostrophomena* and *Ptychoglyptus*. It differs from the latters in being smaller, having different ornamentation, no geniculation. The dorsal interior is also different in the three genera (*Grorudia*, Pl. 1, figs. 10—11, *Ptychoglyptus* pl. 1, fig. 2, *Paleostrophomena* cf. WHITTINGTON & WILLIAMS 1955, pl. 39, figs. 68—70, textfig. 4b). The teeth and the ventral interior is essentially the same in all three genera.

Distribution: Grorudia is found in zones 4aβ and 4bα (lowest part) in the Oslo region, and in the Tramore Limestone, County Waterford, Eire.

Grorudia grorudi sp. n.

Pl. 1, figs. 7, 10—11, textfigs. 11D, 16.

Type data: The holotype is PMO 66939, the cast of a dorsal interior from zone 4aβ, Tåsen, Oslo district.

Material: More than 25 casts of the interiors and complete specimens. The exact number of exteriors can not be given as they occur together with *Alwynella osloensis* which is of similar shape and size and has the same type of ornamentation.

Description: A specimen of average size is 10 mm wide, and 4 mm long. Valves with sharp cardinal angles and slight convexity. The sculpture shows traces of differentiation, every third to fifth rib is generally stronger than the rest. This differentiation is differently developed, in many specimens all ribs seem to be of equal size. The areas are comparatively high, semiequal. There is no apical foramen. The ventral interior does not have any distinct muscle impressions, a pair of diverging vascular impressions are prominent, and between them there are a few thin septa. The dorsal interior has branchial lamella divided by a diverging pair of vascular impressions. The cardinal process is not developed, and there is only a large swollen area on the top of the notothyrium. The teeth are double, the hinge-line is not denticulated. The shell substance is finely pseudopunctate.

Remarks: G. grorudi differs from *G* (?) *glabrata* in being much smaller, in the slight differentiation of the sculpture, and in the branchial lamella being more strongly developed. As to the exterior it is difficult to discriminate it from the contemporaneous *Alwynella osloensis*, which has a similar sculpture and is of the same size, convexity and shape. The growth-lines are, however, differently developed (cf. p. 57), and the interior of the two species are of course very different.

A similar species is found in the Tramore Limestone (stage III, with *Trinucleus hibernicus*), county Waterford, Eire. It differs from the species described here in being extremely wide (hingeline/length ratio more than 4).

Distribution: G. grorudi is found in zone 4aβ of the Oslo district. Probably this species occurs in other districts too, but since the interior cannot be studied in any of the specimens, it is difficult to distinguish this species from *Alwynella osloensis.*

Grorudia (?) *glabrata* sp. n.

Pl. 1, figs. 4, 8, 18, Textfig. 11A

Type data: The holotype, PMO 66929, is a cast of a dorsal interior from the transitional layers between zones 4aβ and 4bα at Sentralinstituttet, Blindern, Oslo district.

Material: 2 dorsal interiors, 2 ventral interiors and a large number of fragmentary exteriors.

Diagnosis: Large, flat *Grorudia* with differentiated sculpture, high areas, strong, diverging vascular impressions and small, circular branchial lamella.

Description: Comparatively large species (the holotype is 15 mm wide and 10 mm long). Both valves are rather flat, outline hemicircular, cardinal angles right. Sculpture differentiated, 6—7 more delicate ribs between each stronger one. The areas are comparatively high, the ventral one is the largest. The delthyrium is narrow, with an angle of about 60°. There does not seem to be a pseudodeltidium.

The ventral interior is, just as in *Grorudia grorudi*, dominated by the strong, diverging vascular impressions. The muscle impressions can not be seen, but a number of subparallell septa between the vascular may have some connection with them. The margin of the valves have strongly marked ciliar grooves, for a space of about 0,75 mm from the margin. It is remarkable that the vascular branches all terminate into such a groove, although all grooves are not provided with a vascular branch.

The dorsal interior is dominated by the branchial lamella, which are smaller and more uniformly circular than in *G. grorudi*. There is no real cardinal process, only an undifferentiated swelling of the notothyrial floor. The teeth and sockets are double, the distalmost being the smaller ones.

Remarks: The differences as to internal structures between this species and *G. grorudi* are mentioned above. They also differ considerably as to size, shape and ornamentation. There may be some doubt as to whether *G.* (?) *glabrata* should be referred to *Grorudia* at all. Probably it is closer to *Paleostrophomena*, and at least it is a transitional link between the two genera. It differs from *P. concava* and other species of *Paleostrophomena* in not having concentric rugae and geniculation, in having comparatively larger branchial lamella and in the lack of a cardinal process.

Distribution: As yet this species has only been found at the type locality and some localities in the neighbourhood. They are all in the transitional layers between zones 4bα and 4aβ. Most of the specimens occur in layers which should be regarded as belonging to zone 4bα, since they occur together with *Ullerella holtedahli* (HENNINGSMOEN) and *Chasmops* sp. Probably the holotype itself also comes from these layers, but it is impossible to date it as accurately as the other spemens.

Genus *Paleostrophomena* HOLTEDAHL 1916 (em. ÖPIK 1933)

Paleostrophomena (?) *majori* sp. n.

Pl. 1, fig. 13.

Type data: The holotype, PMO 64790, is the cast of a ventral interior from the middle part of the Bryozoan zone at Saltboden, Frierfjorden, Langesund-Gjerpen district.

Material: 5 ventral interiors (casts).

Diagnosis: Paleostrophomena species without geniculation and well defined ventral muscle impressions, and with sharp cardinal angles.

Description: Fairly large species, the holotype is 26 mm wide and 17,5 mm long. The valve is almost flat, without any geniculation. The sculpture is not known, but judging from the grooves on the margin of the interior, the distance between the major ribs was about 1,5 mm. Concentric rugae (4—7) are strong at the hinge-line. The area is high, with a narrow delthyrium (about 45°) covered with a strongly arched pseudodeltidium. The muscle impressions are small, badly defined, and nearly filled with the large vascular impressions, which are of the usual *Paleostrophomena*-type. The teeth are small, and double. Both pairs are of about the same size. The interior surface is finely pitted, indicating a punctate structure of the valve, possibly of the same type as that found in *Ptychoglyptus*. There are long, undifferentiated ciliar grooves along the margin.

The dorsal valve is unknown.

Remarks: P (*?*) *majori* differs from the type species, *P. concava* (SCHMIDT) in the absence of geniculation, in being smaller, having a narrower delthyrium, and in the concentric rugae of *P.* (?) *majori* appearing to be restricted to the area near the hinge-line. It differs from *P. magnifica* WILLIAMS (1955) in the short and badly defined muscle impressions.

Together with *Grorudia* (?) *glabrata*, *P.* (?) *majori* forms a continuous series of species from the typical *Grorudia* to *Paleostrophomena* (*G. grorudi* — *G.* (?) *glabrata* — *P.* (?) *majori* — *P. concava*). The stratigraphic occurrence of the species is also in accordance with this theory.

Distribution: *P.* (?) *majori* is found in the Echinosphaerites and Bryozoan zones in the Langesund—Gjerpen district. A very small specimen is found at the base of the Echinosphaerites zone, while the majority of the specimens are collected 85 m. higher, in the middle part of the Bryozoan zone.

Genus *Leptestia* BEKKER 1922.

Leptestia aff. *jukesi* (DAVIDSON 1871).

Pl. 4, fig. 4.

For synonymy, see HARPER (1952, p. 101) and ÖPIK (1930, p. 125—129).

Material: 5 ventral interiors (casts).

Description: The moderately convex specimens are about 25 mm wide and 19 mm long. The area is high, the dental plates short, and the teeth strong and triangular. The muscle impressions are ovoid, with longitudinal septa, probably between the adductors and diductors. The large rounded ovarian impressions are strongly impressed in the valves, and show a number of radial, high, thin septa. The vascular arches are less developed than in typical specimens of *L. jukesi* (and *musculosa*). The interior surface of the valves is strongly pitted, indicating that the shell structure was coarsely pseudopunctate.

Remarks: The present material is too small to throw any light on the relationship of *L. jukesi* and *musculosa*, but they differ from them only in the marginal branches of the vascular arches not being so strongly developed. The ventral interiors are rather like those of certain Orthids as to the shape of the muscle impressions, and especially those of the ovaria. The presence of pseudopuncta, however, shows that the specimens belong to the Strophomenida, and in this group they can only be placed in the genus *Leptestia*, as no other Strophomenid genus has these features.

Distribution: In Norway in the Bryozoan zone in the Langesund/Gjerpen district. In Esthonia *L. musculosa* is found in zones C_1–$C_{2\beta}$. In Eire *L. jukei* is found in beds of similar age.

THE GENUS *Leptelloidea* JONES *1928* AND RELATED GENERA

The genera of the subfamily Leptestina belong to three distinct groups. The first has flat, generally large valves, double teeth, constant ventral interior (of the *Paleostrophomena*-type) and variable dorsal interior. (*Paleostrophomena* HOLTEDAHL 1916, em. ÖPIK 1933, *Ptychoglyptus* WILLARD 1928, and *Grorudia* gen. nov.).

The second group has small, generally very convex valves, distinct ventral muscle impressions, elevated branchial lamella. The development of the cardinal process and the denticulation of the hinge-line is very variable. (*Leptella* HALL & CLARKE 1892, *Leptelloidea* JONES 1928, *Sampo* ÖPIK 1933, *Leangella* ÖPIK 1933, *Leptellina* ULRICH & COOPER 1938, *Diambonia* COOPER & KINDLE 1939, *Benignites* (*Benignites*) HAVLICEK 1952, and *Benignites* (*Leptestiina*) HAVLICEK 1952). The third group consist only of the type genus *Leptestia.*

Within the second group, *Leangella*, and *Diambonia* are well defined, and are discussed below. *Leptella* in not well known, and is not considered here.

There are probably synonyms among the other generic names mainly because the opinions of the taxonomic value of certain structural features have differed considerably.

In the present material two species belonging to this group are represented by a very large number of specimens from several localities and horizons. The variation has been studied in order to find which features were constantly variable, and which were variable during the individual growth and with changing ecology.

The sculpture, outline, size, angle between and curvature of areas, outline of ventral muscle impression and size and frontal outline of branchial lamella were all too variable too be used as taxonomic features at the generic and subgeneric level. In most cases they could not be used to distinguish species. The only feature which is both caracteristic and constant for the genus or subgenus, seems to be the ventral vascular system. Three types are found in the groups of genera considered here. a) the *Leptelloidea* type, with triangular ovaria along the hinge-line in the vascula cruralia, large frequently branching vascula spondylaria, and reduced vascula media (= the *Sowerbyella* type, cf. p. 37).

b) the *Sampo* type, with almost the whole interior surface covered with the broad anastomosing vascular branches. Most of the branches belong to vascula cruralia, vascula spondylaria present, but seldom prominent, vascula media not observed. In young specimens an irregular vascular arch is often formed (textfig. 11G).

c) the *oepiki* type, with vascula arches formed by vascula cruralia in old specimens united with the broad, unbranching vascula spondylaria, vascula media reduced.

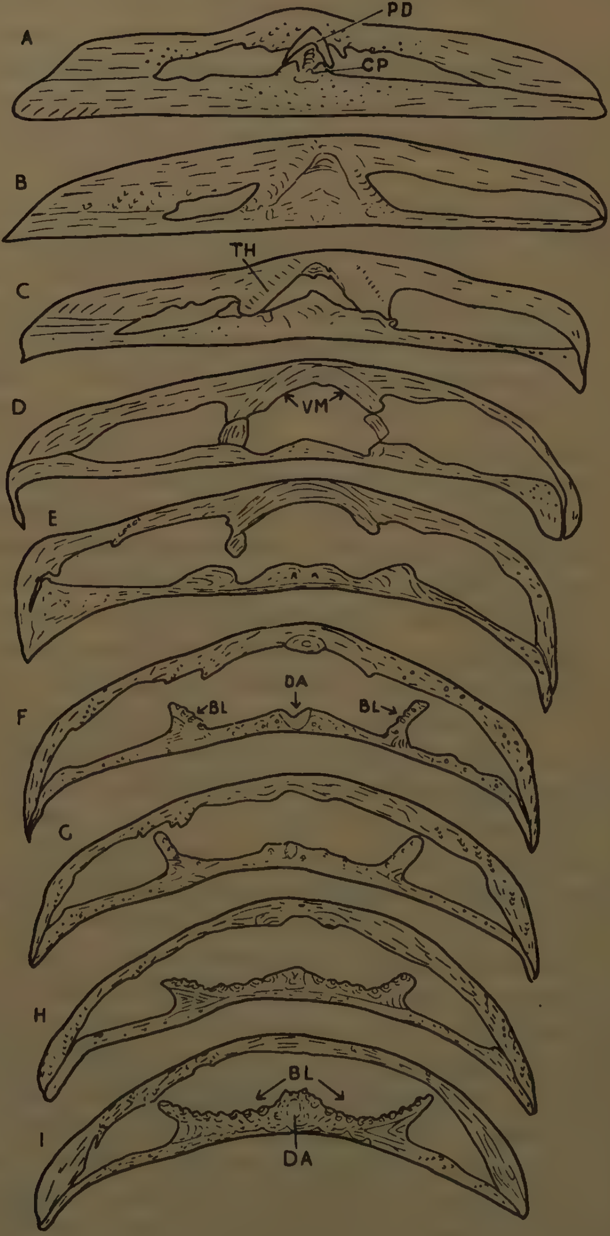
Havlicek (1952, p. 426) indicated that the ventral muscle impressions in *Leptelloidea leptelloides* are different from those found in other species referred to *Leptelloidea*. Although this difference is not so prominent in normal specimens as in the particular one figured by Öpik (1933, Pl. 5, fig. 1), it may be convenient to use *Benignites* Havlicek as a subgenus for species with the same ventral vascular system as *L. leptelloides*, and with diductor impressions with a rounded outline and not surrounding the adductors.

All species with the *Sampo* type of vascular system are included in *Sampo* (*Sampo*), and those with the *oepiki* type are placed in *Sampo* (*Leptellina*) (Ulrich & Cooper 1938).

This arrangement is provisional, since the ventral vascular system is unknown in the type species of *Leptellina* and *Benignites*. It is, however regarded to be more convenient to use these names in a new sense than to introduce new names.

The species which can be refered to the different genera as defined here, are:

Leptelloidea (*Leptelloidea*) — *leptelloides* (Bekker 1922)
Leptelloidea (*Benignites*) — *llandeiloensis* (Davidson).
Sampo (*Sampo*) — *hiiuensis* Öpik 1933, *ruralis* (Reed 1917) *trabeata* (Angelin & Lindström 1880), *indentata* sp. n., ? *derfelensis* (Jones 1928).
Sampo (*Leptellina*) — *oepiki* Whittington 1938, *elevata* sp. n.


A
PD
CP
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There are still some «Leptelloideas» which do not fit into any of these genera as for instance *L.* (?) *rosendahli*, which has ventral muscle impressions like *Sampo* and *Benignites*, but long, narrow and pointed branchial lamella. A similar species is found in the Balclatchie Group in Scotland. Further material will be needed in order to decide if these species should be included in a new genus or subgenus.

Some of the oldest species in this group of genera, *L.* (?) *humboldti* and *L.* (?) *heintzi* sp. n. are not well known, and cannot with absolute certainty be refered to any of the above mentioned genera.

Genus *Sampo* Öpik 1933

Subgenus *Sampo* (*Sampo*) Öpik 1933

Sampo (*Sampo*) *indentata* sp. n.

Pl. 2, figs. 15—16, Pl. 4, fig. 8 Textfigs. 11EFG, P. 18, 19E.

Type data: The holotype, PMO 67135, is the cast of a ventral interior from zone 4bγ, west of Billingstad st. Asker district.

Diagnosis: Strongly curved *Sampo* species with slightly developed vascula spondylaria, no denticulation of the hinge-line, and comparatively large branchial lamella.

Material: About 50 complete specimens, 85 ventral and 30 dorsal interiors and a large number of fragmentary specimens and valves in rock.

Description: Strongly concave convex valves, some specimens almost cylindrical. Cardinal angles acute. Sculpture consisting of few ribs with 8—14 stria between each. The areas are triangular, with rounded ends, and the delthyrium is covered with a slightly convex pseudodeltidium. The notothyrium is filled with the chilidal plates and a strong cardinal process.

The ventral interior shows the characteristic vascular system of the genus, the only difference from the other species, is the slightly developed vascula spondylaria. In the younger species (*hiiuensis* and

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Fig. 18. *Sampo indentata sp. n.* A—I, 9 sections of one specimen. The sections are not parallel. The specimen is from the upper part of zone 4bγ, at Hvalstad, Asker district.

Abbreviations. BL = Branchial lamella composed of flat lying pseudopuncta. CP = Cardinal process. DA = Dorsal axis. PD = Pseudodeltidium. TH = Teeth. VM = Ventral muscle impression.

ruralis) these vascula are much stronger. The muscle impressions are divided into central-anterior small adductors, which migrate anteriorly as the specimen grow older, and large paired diductors with strong growth-lines parallel to the posterior margin. The muscle impressions are deeply impressed in the valve.

A specimen of average size is 17 mm wide and 9,5 mm long.

The vascula in the dorsal valve differ from those in the ventral one in being narrow and unbranching (textfig. 11P). The cardinal process and the chilidal plates are strongly developed. The branchial lamellae are of a rounded outline with a prominent sulcus, and it is longitudinally striated by pseudopuncta parallel to the surface. In adult specimens the lamellae are supported by deposition of secondary tissue. The muscle impressions are not defined. There is a central axis, which at least in young specimens, possibly is open posteriorly (DA in textfig. 18, F. I). It can be traced through the whole length of the branchial lamellae, and can be compared to the structure described by ÖPIK (1933, textfig. 7. *T*) from *Leangella*.

The shell structure is finely pseudopunctate. The puncta seem to be of the same size all over the valves. Along the hinge-line there is a row of pseudopunctae corresponding to the denticles in the younger *Sampo* species. In *S. indentata*, they do not reach the surface of the valve, not even in querontic specimens. (cf. textfig. 18, B, left side).

Remarks: Sampo indentata differs from its congeners in having no developed denticulations along the hinge-line. The vascula spondylaria is slightly developed in contrast to the younger species. It also differs from *S. hiiuensis* in having comparatively large branchial lamellae. Features of less importance, is the fact that *S. indentata* generally is smaller, and more strongly convex than the other species.

S. (*L.*) *derfelensis* resemble *S.* (*S.*) *indentata* both as to exterior and dorsal interior. The ventral vascular systems are, however, different, (cf. WHITTINGTON & WILLIAMS 1955, pl. 39, fig. 73) and the latter species is therefore refered to the subgenus *Sampo* (*Leptellina*) as defined here.

Distribution: S. (*S.*) *intendata* is quite common in zone 4bγ in the Oslo—Asker district, in the shelly facies of this zone. In the same horizon in the Ringerike district there are some strongly curved specimens of which the interior is not known, and they might also belong to this species. It also occurs in the Cyclocrinus Shale and the Cyclocrinus Limestone at Gran, Hadeland district. A smaller variety, with a broad, more or less prominent sinus in the ventral valve is common in zone 4bδ in the Oslo—Asker district, and probably also in zone $4b\delta_2$ (of *Tretaspis kiaeri*) in the Ringerike district. The interiors found in zone 4bδ in the Oslo—Asker district, are identical with those from zone 4bγ, and they are therefore regarded as belonging to the same species in spite of the difference in external shape.

Subgenus *Sampo* (*Leptellina*) Ulrich & Cooper 1938 em. nov.

Sampo (*Leptellina*) *oepiki* Whittington 1938

Pl. 2, figs. 18—19, pl. 4, fig. 6, textfig. 19G, 11O.

1938 *Sampo oepiki* sp. n. — Whittington, pp. 255—257, pl. 10, figs. 15—16, pl. 11, fig. 10.

Material: More than 100 ventral interiors, 17 dorsal interiors and a large number of free complete specimens, complete specimens and valves in rock. As usual in species of this kind, the number of ventral valves is much higher than that of dorsal ones.

Description: A specimen of average size from the Oslo—Asker district is 5,5 mm wide and 2,5—3 mm long. The larger specimens from the Hadeland district are about 11 mm wide and 8 mm long.

The size and convexity is variable. The specimens are generally rounded triangular in outline, and widest along the hinge-line. The sculpture consists of some delicate ribs, and in a few cases a number of scarcely visible stria (6—9) are found between each. Most specimens appear to be smooth. The areas are very high, especially the ventral one, with broad delthyrium and notothyrium. The pseudodeltidium is comparatively small, as is also the cardinal process. The «chilidal plates» are developed such as in *Sowerbyella*.

The ventral interior is dominated by the vascular impressions, and the muscles. The vascular system consists of a pair of vascula media, which are very thin, and directed posteriorly. It is only found in gerontic specimens. A strong pair of vascula (v. spondylaria) are parallel to them, but much broader. (Pl. 4, fig. 6 and textfig. 11 O). The vascula dentalia run from the anterior side of the muscle impressions, parallel to the hinge-line, and turn posteriorly, parallel to the margin of the valves .These vascula are very broad, with irregular, short branches with rounded ends. They are therefore supposed to contain the ovaria. In old specimens these vascula meet the vascula spondylaria, so that a vascular arch is formed. In young specimens, only the vascula dentalia are developed. In older specimens, the vascula spondylaria are observed, and then the fusion of the vascula. The thin vascula media are only observed in highly gerontic specimens.

The muscle impressions are comparatively small, and tripartite, as for instance in *Sampo indentata*, and most other Leptestiinids. The teeth are strong, and accessory teeth, which were very small, have only been seen in a few specimens.

The dorsal interiors show the cardinal process, which is low, rounded and wide. The sockets are prominent, and those of the accessory teeth can be seen in most of the specimens. The branchial lamellae are large, with pointed anterior flanks, and they are radially striated, indicating that they consist of parallel pseudopuncta, such as in other Leptestiids. The median sulcus in the branchial lamella varies as to strength and width. The vascular system of the dorsal valve is only slightly impressed in the valve, and it seems to be similar to that of *Sampo indentata*.

Remarks: *S.* (*L.*) *oepiki* differs from *S.* (*L.*) *derfelensis* in the sculpture, convexity, and the size of the areas (cf. textfig. 19, G). The interiors are quite like, and the specimens are undoubtedly nearly related.

There are several different types of growth of this species in the material dealt with in this paper. One type, which is found in the Oslo—Asker district, is small, strongly convex, and distinctly triangular in young specimens. The other type which occurs in contemporaneous or slightly younger layers in the Hadeland district (and possibly Ringerike) is larger, not so convex, and with a more rounded outline. The two types are not separated into different species or subspecies, because the author is inclined to believe that the first type is an ecological form found in clay and clay-silt environment with little or no lime, and that the other type is restricted to marl and limestone environment. The first type is also in most cases accompanied by a microfauna (see below), while the second is found with a macrofauna.

Distribution: This species appears to be a good guide-fossil. It occurs in the zone 4bα in the Oslo—Asker, Ringerike and Hadeland districts. The small type seems to be restricted to the middle part of the zone in the Oslo—Asker district, where it occurs together with *Steusloffia costata* and dalmanellids. The larger type is found in Hadeland, and possibly also in Ringerike, together with large Strophomenids and Orthids. Transitional forms are found in the more calcareous upper part of zone 4bα in the Oslo—Asker district, and in the middle part of the zone in Ringerike. It is also found in the Coelosphaeridium beds of the Ringsaker district. This species also occurs in the Lower Longvillian of Shropshire and Wales, together with i.a. *Eoplectodonta acuminata.*

Sampo (*Leptellina*) *elevata* sp. n.

Pl. 6, figs. 11—12.

Type data: The holotype, PMO 7513, is the cast of a ventral interior from the lower portion of zone 4bα at Gomnes—Rud, Ringerike district.

Diagnosis: Small *Leptellina* species with valves higher than long, and with a prominent marginal groove.

Material: 3 casts of the ventral interior, 4 complete, free specimens and some casts of exteriors and fragments.

Description: The holotype (pl. 6, figs. 11—12) is 7 mm wide and 4,5 mm long. This species is remarkable in being higher than it is long. The specimens are very small, and at the later stages of growth, the margin was almost hemicylindrical, flattening out at the latest stages of growth. In cross-section, the hingeline is found above the middle of the specimens. The vertically striated medio-marginal groove is slightly lower than the hinge-line. The muscle impressions are small, subpentagonal, rounded posteriorly. The areas are low, and the angle between them is generally less than 180°. The vascular system is similar to that of *S.* (*L.*) *oepiki.* The dorsal valve and the shell structure is unknown.

Remarks: This species is closely related to *S.* (*L.*) *oepiki,* but differs from it in the peculiar vertical growth. It is possible that further research may show that it is a subspecies of *oepiki.*

Small specimens of *S.* (*L.*) *elevata,* in which the marginal fringe is broken off, resemble species of *Leangella* and *Diambonia.* If a diaphragm is present in the dorsal interior, the species may be refered to the first genus with some doubt. Because of the absence of the septum in the ventral interior, it cannot be a *Diambonia*. The vascular system is of the type found in *Leptellina*, indicating that the species should be referred to that subgenus.

Distribution: The species is with absolute certainty only known from the type locality, and zone 4bα. In other localities in the same zone in the Ringerike and Oslo—Asker districts, there are some specimens, which might be referred to this species. The marginal fringes are, however, at least partly broken off, and the specimens can therefore not be definitely determined. In this species, the vascular system (most of the vascula dentalia) is found in the part which is easily broken off.

Genus *Leptelloidea* JONES 1928

Subgenus *Benignites* HAVLICEK 1952, em. nov.

Leptelloidea (*Benignites* ?) *heintzi* sp. n.

Pl. 4 figs. 10—11.

Type data: The holotype is PMO 66651, the cast of a ventral interior from zone 4aα_3, at Ravaldsjøelven, Sandsvær/Eiker district.

Material: 4 ventral interiors, and some casts of the exteriors of valves.

Diagnosis: A small *Benignites* (?) species, with subtriangular outline, small, well defined muscle impressions in the ventral valve, diverging vascula spondylaria, and sometimes a small disc.

Description: A ventral valve of average size 7 mm wide and 4,5 mm long. The valves are moderately convex, and appear to be smooth, a feature which might be due to the mode of preservation of the specimens. The outline of the valves is somewhat variable, generally rounded triangular. The areas are comparatively low, with clearly visible chilidium. The ventral interior shows small muscle impressions, bluntly pointed posteriorly, and with strong vascula spondylaria diverging from their ends. In some interiors there is a small disc. but without a real geniculation. The dorsal interior is unknown. Judging from the pits found in the casts of the ventral interior, the shell structure was coarsely pseudopunctate. The shell substance itself is not preserved.

Remarks: This species resembles *L.* (*B.*) *llandeiloensis* as to the vascular system and shape, but it has no bilobed muscle impressions, and is much smaller. Except for the coarse pseudopuncta and the disc, it is also quite like *Leangella*, although it is larger than usual for that genus.

L. (*B.?*) *heintzi* is interesting, being among the oldest species of this group of genera (*Leptelloidea* s.l.).

Distribution: In the zone 4aa_3. In the type locality it is associated with *Trinucleus* cf. *foveolatus*, *Ogygiocaris dilatata dilatata* and small dalmanellids and ostracods.

Leptelloidea (s. l.) *rosendahli* sp. n.

Pl. 2, figs. 4—5, textfig. 11D.

Type data: The holotype, PMO 66984, is the cast of the interior of both valves, from the Coelosphaeridiumbeds, Fangberget, Ringsaker district.

Material: 2 complete casts of the interior of both valves, 6 ventral interiors (casts), and a number of casts of the exteriors of valves.

Diagnosis: Leptelloidea (s. l.) species with posteriorly pointed branchial lamellae, strong crural plates, ventral muscle impressions bounded by parallel lateral ridges, and with coarsely pseudopunctate valves.

Description: A specimen of average size is 6,5 mm wide and 6 mm long. The valves are strongly convex, with rounded triangular outline. Sculpture on the holotype consisting of about 16 ribs with indications of fine striae between them. In other specimens, these striae are stronger, almost of the same strength as the ribs. There are 4—5 between each rib. The areas are comparatively high, and concave. The delthyrium is broad, and the chilidal plates are developed just as in *Sowerbyella.*

The ventral interior shows the muscle impressions, which have parallel lateral sides. The adductor impressions is placed further in front, and is small. The boundaries of the muscle impressions are smooth laterally and spinose posteriorly. The teeth are small.

The dorsal interior shows the large, posteriorly pointed branchial lamellae, and very strong crural plates which seem to be double. The interior of the valve is striated longitudinally, and has a pair of vascula media between the branchial lamellae.

The shell substance is not preserved, but the pits in the casts show that the valves were coarsely pseudopunctate. In the middle of the valves, the pseudopuncta were almost parallel to the surface, as for instance in *Christiania*.

The cardinal processes seem to be double in one of the dorsal interiors, in the other, this feature is destroyed. The presence of a double cardinal process is also known from *Leptelloidea* (*?*) *musca* ÖPIK (1933, pl. 6, fig. 2), and is probably a feature of less importance.

Remarks: This species differ considerably from all other species of the genus, especially in having pointed branchial lamella. *L. musca* ÖPIK has similar ventral muscle impressions, but the adductors are placed more posteriorly in *L. rosendahli*, and the branchial lamellae are also much larger, and more well defined than in *musca*. The shell structure is different too. Because of the absence of a diaphragm, and the coarse pseudopuncta, it cannot belong to *Leangella*.

The author has observed a dorsal valve from the Balclatchie Group of the Girvan district, Scotland, which is rather similar to that of *L. rosendahli*.

Distribution: L. rosendahli is found in the Coelosphaeridium zone of the Ringsaker district only. It has been collected from two localities in this district, and seems to be common in both.

Leptelloidea (s.l.) sp.

Pl. 4, fig. 5.

Material: One fragmentary cast of a dorsal interior, and a cast of a dorsal exterior.

Description: The exterior is 6 mm wide and 4 mm long. The interior was considerably larger, about 12 mm wide and 5—6 mm long. The valves are rather flat, and appears to be smooth. The branchial lamellae are turned outwards anteriorly, such as for instance *L. llandeiloensis*, and they are longitudinally striated. The crural plates are thin, short and rather high. The sulcus on the branchial lamellae is sharp and high. The specimens were thinshelled.

This species is mentioned here because of its stratigraphic occurence. The material is too limited for a specific determination.

Distribution: The two specimens were collected in the transitional layers between the zones $4a\alpha_4$ and $4a\beta$ in Muggerudkleiva, Sandsvær—Eiker district. This is an unusually low horizon for species of this type in Norway.

THE GENERA *Leangella* ÖPIK 1933 AND *Diambonia* COOPER & KINDLE 1936.

The type species of *Leangella* is *L. scissa* (SALTER) (The type selected by ÖPIK 1933 was *L. scissa* var. *triangularis* (HOLTEDAHL 1916). This form is identical with the typical *scissa*. The species described by ÖPIK (l.c.) as *L. triangularis* (HOLTEDAHL 1916), however, is another species. The type species of *Leangella* is therefore *L. scissa*).

The differences between *Leptelloidea* and *Leangella* are: the muscle impressions in the ventral valve have an indentated margin, and are elongate in *Leptelloidea* while they in *Leangella* are subcircular, and have a smooth margin. *Leptelloidea* also has open puncta while *Leangella* only has ordinary strophomenid pseudopuncta.

In the dorsal valve, *Leangella* has a diaphragm, which is not found in *Leptelloidea* and *Sampo*. The branchial supports are thicker in *Leangella*, and they are smaller than in most species of *Leptelloidea*, with the exception of *L. musca*, which probably is the ancestral form of *Leangella*.

The genus *Diambonia* was made to include species intermediate between *Leangella* and *Leptelloidea musca*. The ventral valve is largely similar to that of *L. musca*. The muscle impressions are in some species more elongate and diverging in *Diambonia*. The dorsal interior is similar to that of *Leangella*. A median septum is found in the ventral valve. ÖPIK (1933, p. 42) included one of the species now refered to *Diambonia* in *Leangella*, in spite of the median septum in the ventral valve. It therefore seems correct also to include species without this median septum in *Diambonia*.

The position of *Leptelloidea musca* is still uncertain. It is doubtful whether it should be included in *Diambonia* as defined here, or if it shall remain in *Leptelloidea*, as a deviating species of that genus. *L.* (?) *musca* is from the lower Middle Ordovician, *Diambonia* appears to be restricted to the Middle and Upper Ordovician, and *Leangella* is recorded from the Upper Ordovician and Silurian, with the exception of one species from the upper part of the Middle Ordovician of Norway (*L. hamari*).

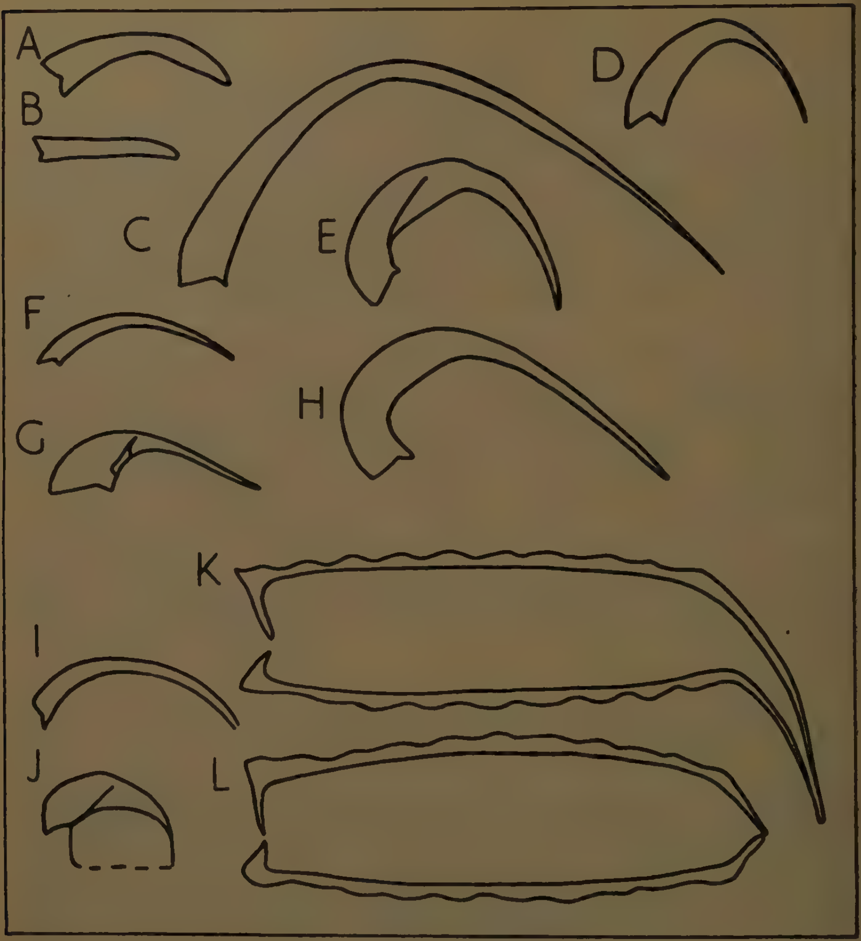

Fig. 19. Cross-sections of some Plectambonitid species. Magnification about 9/10. A. *Eoplectodonta acuminata* (Holtedahl 1916), from zone 4bα in the City of Oslo, Oslo district. B. *Alwynella osloensis* sp. n. from zone 4aβ at Tåsen, Oslo district. C. *Eoplectodonta* (?) *rhombica* (McCoy 1852), from zone 4bδ in the Hadeland district. D. *Leptelloidea* (s.l.) *rosendahli* sp. n. from the Coelosphaeridium Beds of Brummundal, Ringsaker district. E. *Sampo* (*Sampo*) *indentata* sp. n. from zone 4bγ at Hvalstad, Asker district. F. *Sowerbyella serica askerensis* subsp. n. from the Lower part of zone 4bγ at Hvalstad, Asker district. G. *Sampo Leptellina*) *oepiki* Whittington 1938, from the middle part of zone 4bα in the City of Oslo, Oslo district. H. *Eoplectodonta* (?) *percedens* (Holtedahl 1916). from zone 4bβ at Arnestadtangen in the Asker district. I. *Sowerbyella sericea*

Diambonia (?) *leifi* sp. n.

Pl. 2, figs. 9—11.

1916 *Plectambolites convexa* PANDER 1830 — HOLTEDAHL, p. 78, pl. 14, fig. 9.

Type data: The holotype, PMO 57536, is the cast of a dorsal interior from 18 m above the base of the Mastopora zone, just N. of the pier at Stranda, Frierfjord, Langesund—Gjerpen district.

Material: 43 casts of valves, 3 of the dorsal and 12 of the ventral interior.

Description: Small, strongly concave-convex species. Three specimens are 7,5—6,5—5,5 mm wide, and 4,0—4,5—4,5 mm long. Ventral area high, triangular with open delthyrium. Dorsal area low, subparallel. The sculpture is only seen on a few specimens. Generally it is not preserved, because of the contactmetamorphosis of the rocks in which the specimens occur. When preserved, the sculpture consists of a number (about 3—4) striae. No radii can be seen on the material available. The outline of the specimens is generally subtriangular, with sharp cardinal angles. Some with a more rounded outline and right cardinal angles does also occur. In some specimens the diaphragm in the dorsal valve is reflected as a faint ridge on the exterior of the valves.

The dorsal interior has a pair of sharply pointed, triangular branchial lamellae, a median septum and a complex, not bifid cardinal process. The socket plates are parallel to the hinge-line. There is a distinct diaphragm parallel with and near to the margin of the valves.

The ventral interior is similar to that of *L.* (?) *musca* (ÖPIK 1933, pl. 6, fig. 3, textfig. 15) as to the shape of the muscle impressions. However, in most specimens there is a groove corresponding to the diaphragm in the dorsal valve.

The shell-structure is unknown, because of the state of preservation of the material. No traces of pseudopunctae or punctae can be seen in the casts, as was the case with *Leptelloidea* (?) *musca*, but this might be due to the coarse surface of the cast.

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soudleyensis JONES 1928, from the Mjøsa Limestone, at Helgøya, Hamar—Nes district. J. *Leangella hamari* sp. n. from the Cyclocrinus Beds at Furuberget, Hamar—Nes distrikt. (cf. textfig. 18). K, L. *Ptychoglyptus valdari* sp.n. from zone 4bα at Billingstad, Asker district. L. is a large, normal specimen, and K. is a specimen with dorsalwards geniculation.

Remarks: This species was referred to *Plectambonites convexa* PANDER by HOLTEDAHL because of its similarity to material so labeled from the Kurkuse beds. However, these Esthonian specimens belong to *Leptelloidea* (?) *musca.*

The ventral interior of *Diambonia* (?) *leifi* is similar to that of *Leptelloidea* (?) *musca,* except for the teeth being slightly stronger in *L.* (?) *musca,* and the ventral area being considerably higher in *Diambonia* (?) *leifi.* It differs from all other species of *Diambonia* in not having a median septum.

The dorsal valve differs from those of most Diambonias and Leangellas in the branchial lamellae being far apart, so that the low median septum is placed between the lamellae, without being fused to them, as in *L.* (?) *musca* and other species. In this feature *Diambonia* (?) *leifi* resembles *Leptelloidea* (?) *etheridgei* (REED 1917). This species, however, has no diaphragm, and the ventral interior is quite different.

Because of the structure of the branchial lamellae and the diaphragm, *Diambonia* (?) *leifi* cannot be referred to *Leptelloidea* (or *Sampo*), and it cannot be included in *Leangella* because of the shape of the ventral muscle impressions. It is referred to *Diambonia,* but the sharp separation of the branchial lamellae, and the absence of a median septum in the ventral valve makes it uncertain whether this is correct.

Distribution: In the Langesund—Gjerpen district only. It ranges from the upper part of the Bryozoan zone to the top of the Mastopora layers.

Diambonia anatoli sp. n.

Pl. 2, figs. 6—8, texfig. 11R.

Type data: The holotype, PMO 66985, is the cast of a dorsal interior from zone 4bα, in a roadside section just N. of Halsen, Nesøya, Oslo—Asker district.

Material: 4 casts of the dorsal interior, 12 of the ventral interior and a large number of casts of the valves, and partly exfoliated valves.

Description: An adult specimen of average size is 5 mm wide and 4 mm long. The specimens are strongly concave-convex, of variable shape, mostly rounded triangular. Ventral area low triangular, delthyrium narrow, 45°, the development of the pseudodeltidium depends on the age of the specimen, being hardly visible in young ones, and large in the older. The dorsal area is rectangular and comparatively high. Chilidal plates small, cardinal process trifurcate. Both areas are slightly concave, the angle between them is about 180° in young specimens, and considerably less in older ones.

The sculpture consists of 5—7 radii. Striae are only faintly indicated on a few specimens.

The ventral interior is dominated by the diverging muscle impressions, the border of which is dentated in most specimens. The adductor muscle impressions are elongated pyriform. There is always a median septum, but it varies as to length and depth. In old specimens it tends to be flatly wedge-shaped. In most specimens there is a groove parallel to the margin of the shell, corresponding to the diaphragm of the dorsal valve. One gerontic valve has a strong, smooth bounding ridge around the muscle impressions, and a very narrow adductor impression. In this it resembles *Leangella*, but it differs from it in the elongated outline of the diverging muscle impressions. The vascular system is remarkably similar to that of certain dalmanellids (textfig. 11R). It consists of two pairs of main vascula, the v. dentalia, which have two large branches, and v. spondylaria. All four vasculae branch frequently without forming a vascular arch. No ovarian impressions are found.

Dorsal interior with coherent branchial lamellae with a strong median sulcus, and rounded outline. Socket plates strong, highest at the ends. Diaphragm strongly developed, placed comparatively far from the margin. It has a slightly more triangular outline than the valve.

Remarks: Diambonia anatoli differs from *D. gibbosa* (WINCHELL & SCHUCHERT), the type species, in having a shorter median septum, and from *D. septata* (COOPER) in having no spines on the diaphragm and narrow, long and diverging muscle impressions.

Distribution: This species is found from several localities in zone 4bα in the Oslo—Asker district. It is also found in the same zone in one locality in Ringerike.

Leangella hamari sp. n.

Pl. 2, figs. 1—3, textfig. 19J, 20.

Type data: The holotype, PMO 37879, is an etched complete specimen from the Cyclocrinus Shale of Furuberget, Hamar—Nes district.

Material: 32 free specimens, some of them etched to show the interiors, one cast of the dorsal interior, and a large number of valves in rock.

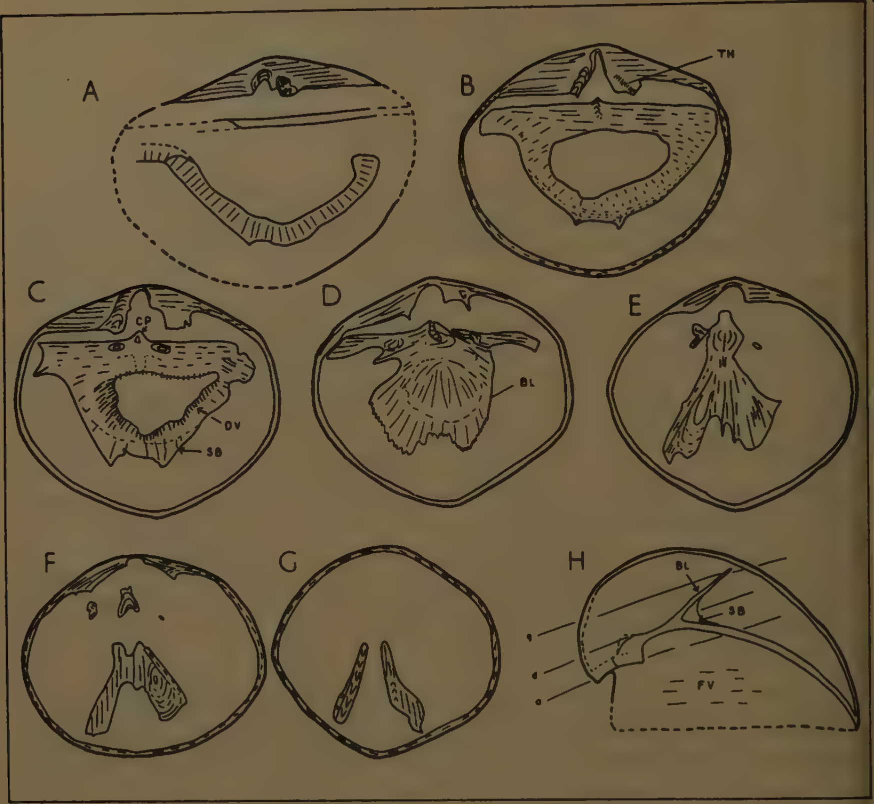

Fig. 20. *Leangella hamari sp. n.* A—G, 7 parallel sections of a specimen. The approximate position of the sections are shown in fig. H (a—d—g). H. Longitudinal section of another specimen. The ventral flange (FV) is not visible in the section, and is indicated by a broken line in order to show the outline of the specimen.

Both specimens are from the Cyclocrinus shale, at Furuberget, Hamar—Nes district.

Abbreviations. BL = Branchial lamella. CP = Cardinal process. DV = External surface of dorsal valve, with fine striation. FV = Lateral ventral flange. SB = Supporting tissue in connection with the branchial lamella. TH = Teeth.

Description: A specimen of average size is 7 mm wide and 5,5 mm long. The valves are rounded triangular in outline, strongly concave-convex. Ventral area low, triangular, the delthyrium has an apical angle of about 90°. Dorsal area rectangular, low, both areas strongly concave. The sculpture consists of a large number of striae (18—22) with 5—7 radii between each.

The ventral interior has small, rounded muscle impressions bounded by a smooth ridge. The dorsal valve has branchial lamellae with two sharply pointed ends, each supported by a septum, as in the specimen of *Leangella scissa* figured by JONES (1928, pl. 25, fig. 10). There is a strong diaphragm near the margin of the valve.

The shells are pseudopunctate. The numerous, comparatively large puncta are arranged in radial rows.

Remarks: This species is a typical *Leangella*, as indicated by the muscle impressions in the ventral valve, and the shape of the branchial lamellae and the diaphragm in the dorsal one. It is rather like *L. scissa*, the type species, from which it differs as to the sculpture (more striae), and in addition to the ventral muscle impressions being smaller, and the diaphragm being placed closer to the margin of the valves. It differs from other species of *Leangella* in the shape of the branchial lamellae, and the outline of the diaphragm.

L. hamari is the oldest typical *Leangella* species known. *L. scissa* is recorded from the uppermost Ordovician, and the other members of the genus are known from the Lower and Middle Silurian. However, a dorsal interior, similar to that of *L. hamari* has been collected by the author in the Balclatchie Group in the Girvan district, Scotland.

Distribution: In the Cyclocrinus Shale in the Hamar—Nes district exteriors of *Leangella*-like brachiopods are found in a large number of localities in the Oslo Region, but only those which can be determined with absolute certainty are included here. Further collecting will definitely extend our knowledge of the distribution of the three last mentioned species.

Subfamily Sowerbyellinae ÖPIK *1930.*

As defined here, this subfamily comprise Sowerbyellidae with a dorsal foramen (= Sowerbyellen-grube of ÖPIK 1933), which may be atrophied in some young specimens, simple teeth, a double ventral cavity, and generally without raised branchial lamellae.

Two, or three lineages are found in this subfamily. The first one is that of the genus *Sowerbyella* itself. In this paper it is restricted to species with branchial lamellae bordered by radially arranged, more or less flatly inclined pseudopuncta. There is generally a pair of submedian septa. The earliest representative of this lineage is *Sowerbyella llandeiloensis* WILLIAMS (1949)[1]. Other typical members are *S. sericea* with sub-species, and *S. semiluna* ÖPIK. *Eochonetes advena* REED, *S. ringsakerensis*. *Eoplectodonta* (*?*) *rhombica* (McCOY) and *E.* (*?*) *percedens* HOLTEDAHL may also belong to this lineage. They differ from the typical members in having denticulated hingelines of different structure.

The second Sowerbyellind lineage consists of species with branchial lamellae bounded with oval, smooth ridges, not composed of pseudopuncta. There are seldom septa between the lamellae, but they are divided by a diagonal vascular septum or groove. If it looks as if the median septa are present, it is in most cases the median margin of the branchial lamellae, which is elevated. In some younger species, both margins are raised, so that the species has 6 septa. In contrast to the previously mentioned group, most of these species have a denticulated hingeline of an uniform type. The structure of these denticulations are described below (cf. *Eoplectodonta acuminata*). The earliest representative of this lineage, is «*Sowerbyella*» *antiquata* JONES[2], and other members are some from the «*S.*» *rhombica* and *quinquecostata* groups, and most species which previously were grouped under *Thaerodonta* WANG, *Plectodonta* and *Eoplectodonta*. The difference between the two latter genera lies in the development of the branchial lamellae, which are level with the surface of the valve in *Eoplectodonta*, and have strongly elevated lateral margins, while they are pointed laterally in *Plectodonta*. *Thaerodonta* WANG (1948) was founded on species which were supposed to have denticles in the dorsal valve, and sockets in the ventral. It was assumed that the opposite was the case in *Plectodonta* and *Eoplectodonta*. The author's studies has shown that there are denticles both in the dorsal and ventral valves in all these genera, and the sockets are merely the interspaces between the denticles. *Thaerodonta* must therefore be regarded as a synonym of *Eoplectodonta* as defined here.

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[1] As mentioned below, *S. antiquata* JONES might belong to another lineage. *S. llandeiloensis* (= *S. antiquata llandeiloensis*) WILLIAMS (1949) is therefore regarded as being a separate species, provisionally including the older forms of the genus, with less developed interior.

[2] As figured by JONES (1928, pl. 21, fig. 11). Another species also appears to have been described under this name, since specimens with a dorsal interior like *S. llandeiloensis* have been included in this species. If therefore a lectotype is not chosen, the author select the specimen figured by JONES 1928, pl. 21, fig. 11 as the lectotype of «*S*» *antiquata*. (Sedgwick Museum nr. A 32152b).

Beside these typical lineages, two minor groups are also included in this subfamily, although it is not certain whether this is correct. The first one is *Chonetoidea*, which differs from the typical members as to the structure of the branchial lamellae, which consist of two arches of very large pseudopuncta. The structure of these lamellae is not unlike that of the *Sowerbyella*-group, but the pseudopuncta are much larger and fewer. The dorsal foramen is not known from this genus. The double ventral cavity found in all species of *Chonetoidea* (pl. 2, figs. 21—22), is a feature which points towards placing it in the Sowerbyellinae. According to ÖPIK (1933) has *Aegiria*, with well developed and raised branchial lamellae, developed from *Chonetoidea*. However, the trend of development in *Chonetoidea* is from older species with well defined branchial lamellae to younger ones without them. *Aegiria* also seems to lack the double ventral cavities. *Sericeoidea* LINDSTRÖM 1952, might, however, be included in the group without doubt, either as a subgenus of *Chonetoidea* or as an independant genus.

The other minor group consists of the new genus *Alwynella*, which has a dorsal interior largely similar to that of *Eoplectodonta*, but with unpaired ventral muscle impressions, a feature which distinguishes it from most Strophomenids. Since the genus is so old (Llandvirn—Llandeilo), it is natural to suppose that this is a primitive feature.

It is too early to decide whether the two major groups of this subfamily, that of *Sowerbyella*, *Eochonetes* and *Chonetoidea*, and that of *Plectodonta*, *Eoplectodonta* and *Alwynella* are monophyletic or not. At their first, contemporaneous appearance (zone of *Did. geminus*) they are quite distinct, and no intermediate forms have been found in younger layers. On the other hand, the peculiar structure of the dorsal foramen and the double ventral cavities indicates a common origin.

Genus *Alwynella* gen. nov.

Type species: *Alwynella osloensis* sp. n., from zone 4aβ in the Oslo Region.

Diagnosis: Sowerbyellinids with simple, not bilobed ventral

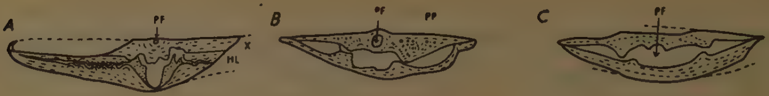


Fig. 21. *Alwynella osloensis sp. n.* A—C, 3 parallel sections of one specimen, showing the dorsal foramen (PF), and the denticulated hinge-line. The specimen is from the lower part of Zone 4aβ, at Ildjernet, Oslo district.

Abbreviations: DE = Denticles of the hinge-line. HL = Hinge-line proper. PF = Dorsal foramen. PP = Pseudopunctae. X = Line of junction of the valves. (external).

muscle impression, dorsal valve with large foramen, small, elevated branchial lamellae median septum and crenulated hinge-line.

Distribution: Upper Lower to Lower Middle Ordovician (zones 4aα_1—4aβ).

Remarks: In spite of the unlobed and probably primitive structure of the ventral muscle impressions, *Alwynella* is included in the Sowerbyellinae because of the dorsal interior being of the same structure as in this subfamily.

Besides the type species, *Alwynella* includes *A. ildjernensis* sp. n. and *A. intermedia* sp. n. It does not look as if any of the previously described species will have to be included in the genus. Some of the specimens figures by Jones (1928, pl. 21, fig. 11) as *Sowerbyella antiquata* apparently belong to *Alwynella* or an early member of the *Eoplectodonta*-group. The latter possibility seems the more probable, since the species has two ventral muscle impressions, instead of one in *Alwynella*. «*S.*» *antiquata* might also represent an intermediate stage between *Alwynella* and *Eoplectodonta*.

Alwynella osloensis sp. n.

Pl. 1 figs. 5, 9, 14, textfigs. 19B, 21.

Type data: The holotype, PMO 66940, is a cast of a dorsal interior from zone 4aβ at Tåsen, Oslo district.

Material: 16 casts of interiors, 8 casts of exteriors, and about 50 complete specimens and valves in rock.

Diagnosis: Alwynella species with acute cardinal angles, slightly differentiated sculpture, large, rounded branchial lamellae. Hinge-line denticulated for about 1/2 to 1/3 of the length in adult specimens.

Description: A specimen of average size is 10 mm wide and 4 mm long. Sculpture consisting of coarse, subequal ribs. Cardinal angles acute. Growth distinctly allometric, young specimens have a higher width/length ratio than the older ones (cf. p. 56). Areas high, triangular. The dorsal one is higher than the ventral, with a large subapical foramen. This opening (cf. textfig. 21) pierces the dorsal valve just behind the socket plates, and is quite big. Serial sections (textfig. 21) prove that the foramen really exists and that it is not merely a deep notothyrial cavity.

Branchial lamellae strong, elevated and evenly circular in outline. A median septum is found between them. The hinge-line is crenulated by denticles which do not appear to be transformed pseudopuncta, since they do not have a central axis. The real teeth are much larger than the denticles, which occur both in the dorsal and ventral valve. The ventral muscle impression is not bilobed, and it is deeply impressed. The shell substance is pseudopunctate, with puncta of moderate size.

Remarks: The difference between this species and *A. ildjernensis* and *A. intermedia* are the shape of the valves, the outline of the branchial lamellae, and the amount of crenulation of the hinge-line. The exterior is quite similar to that of *Grorudia grorudi*, which occurs in the same beds. They might be discriminated by the growth-lines (cf. p. 57, and textfig. 16). The interiors are also quite different.

Distribution: *A. osloensis* is a guide fossil for the zone 4aβ, at least in the Oslo—Asker district. It is also found in the Ringerike district, and probably in Langesund—Gjerpen and Hadeland. From the two latter districts only exteriors are known, so that the identity of the specimens could not be ascertained.

A. osloensis ranges from the very base of zone 4aβ, where it overlaps with *A. intermedia*, to the top of the zone, where it does not seem to occur in the transitional layers to zone 4bα.

Alwynella intermedia sp. n.

Pl. 1 figs. 15—16.

Type data: The holotype is PMO, 66935, a dorsal valve from the transitional layers between zone 4aα_4 and 4aβ at the NW-ern end of Ildjernet, Oslo district.

Material: 3 dorsal and 2 ventral interiors, and some (about 25) exteriors of valves.

Diagnosis: Alwynella species with right cardinal angles, branchial lamellae which vary as to shape and size, generally rounded triangular.

Description: Thick, robust valves with right cardinal angles. An average specimen is 8 mm wide and 3,5 mm long. Sculpture coarse, in some cases every other rib is stronger than the rest. The areas are high, the ventral one higher than in the other *Alwynella*-species. The ventral interior is similar to that of *A. osloensis*. Because of the heavily calcified valves, the marginal restriction of the body-space found in gerontic specimens of other species is found also in ordinary adult specimens of *A. intermedia*. The dorsal interior has branchial lamellae intermediate between those of *A. osloensis* and *A. ildjernensis*. Generally they show a closer resemblance to those of the latter, being triangular.

Remarks: As indicated by the name of this species, it is intermediate between the two other species of the genus. Further studies may prove that it is not a valid species, but only a transitional form between the two others. The right cardinal angles, however, seem to indicate that *A. intermedia* is a separate species. As was the case in the two other species, the growth-lines indicate that the width/length ratio was larger in the young specimens.

Distribution: A. intermedia is found in the transitional layers between zone 4aα_4 and 4aβ in the Oslo—Asker district. The species is only found in a few localities, and appears to have a very restricted stratigraphical range, probably less than 2 m. In all localities it seems to be accompanied by *Ogygiocaris dilatata sarsi* and *Reedolithus carinatus*.

Alwynella ildjernensis sp. n.

Pl. 1, fig. 6.

Type data: The holotype, PMO 66928, is the cast of a dorsal interior from the lower part of zone 4aα_4 at the NW-ern side of Ildjernet, Oslo district.

Material: About 100 casts and valves in rock.

Diagnosis: Alwynella species with acute cardinal angles, coarse sculpture, small, triangular branchial lamellae and 2/3 of the hinge-line denticulated in adult specimens.

Description: An adult specimen of average size is 9 mm wide and 3,5 mm long. The sculpture is coarse, with ribs of nearly equal size. Cardinal angles very acute in adult specimens. Growth-lines indicate that the cardinal angles of the younger specimens were considerably less acute, in some cases almost 90°.

Areas triangular, the ventral one low, the dorsal one much higher, with a large, open foramen at the apex.

The ventral interior can not be distinguished from that of *A. osloensis*. Dorsal interior with small, triangular branchial lamellae and high, thin median node. Teeth and cardinal processes like those of *A. osloensis*.

Remarks: A. ildjernensis differs from *A. osloensis* as to the shape of the shell (which has more acute cardinal angles), as to the outline and size of the branchial lamellae, and partly also as to the amount of denticulation of the hinge-line. The latter feature can only in few cases be used to determine the species, as the material is seldom well enough preserved to show the real amount of denticulation without making a thin section.

Distribution: A. ildjernensis is found in the zones $4a\alpha_{2-4}$ in the Oslo—Asker and Sandsvær—Eiker districts. It might occur in other districts too, but no specimens which can be definitely discriminated from *A. osloensis*, have been found.

This species ranges through a considerable period of time, and a number of different sediments without any noticeable change. It occurs in graptolitic shales, mudstones, muddy siltstones and calcareous mudstones and siltstones. The specimens found in calcareous rocks have a tendency towards having thicker shells than those occuring in noncalcareous rocks.

Genus *Sowerbyella* JONES 1928

Sowerbyella sericea soudleyensis JONES 1928

Pl. 3, figs 1—4, pl. 6, textfigs 19, I and 22

1916 *Plectambonites sericea* (SOW.) — HOLTEDAHL (parte), p. 81, pl. 14, figs 1—3.

1928 *Sowerbyella sericea soudleyensis* var. nov. — JONES, pp. 417—418, pl. 21, figs. 5—6.

Material: More than 50 dorsal interiors, 70 ventral ones, and a large number of exteriors.

Description: The specimens are rounded rectangular in outline, slightly convex, and of moderate size (see diagram, textfig. 22). The

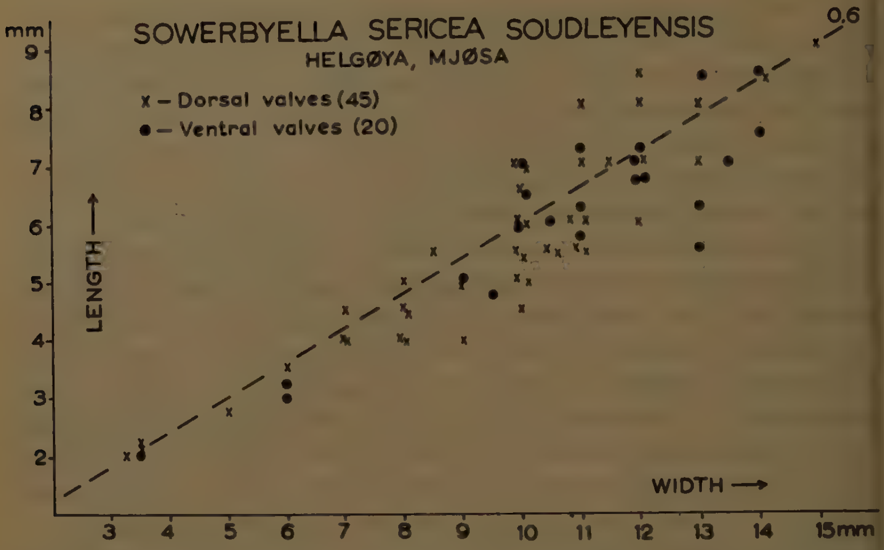


Fig. 22. Diagram showing the variation is size of specimens of *Sowerbyella sericea soudleyensis* JONES 1928, from the Mjøsa Limestone at Helgøya, Hamar—Nes district. The dorsal valves are from the slab figured by HOLTEDAHL (1916, pl. 14, fig. 3, PMO L0085), and the ventral ones are from HOLTEDAHL, pl. 14, fig. 2, (PMO 66977). The dorsal and the ventral valves belong to two different populations.

sculpture is hardly differentiated, with one or two finer striae between each stronger one. The cardinal angles are right or slightly less in adults, and about 60—70° in young specimens. The areas are in one plane in all but gerontic specimens.

The ventral interior shows the diverging muscle impressions with a median septum between them, comparatively strong teeth, and deep ventral cavities, one on each side of the median septum. The muscle impressions are small, and bounded by sharp, smooth ridges.

The dorsal interior shows the wedge-shaped branchial impressions, which are divided into two unequal parts by a pair of vascular grooves. The median borders of the branchial lamellae are raised, forming two slightly diverging septa. The chilidal plates are strongly developed, and the dorsal foramen is large, but does not penetrate the valve. Just as in most other *Sowerbyella* species, the pseudopuncta visible on the interior surface of the valve, are largest around the branchial lamellae, and decrease in size towards the margin. The hinge-line is straigth, and slightly raised, and the margin is thickened in all adult specimens.

A number of young specimens show the development of this subspecies. The outline changes from subtriangular or hemicicular in the young specimens to rounded rectangular in the adult ones. The ratio Width/Length is remarkably constant during the growth of this species (cf. textfig. 22). Most other brachiopod species have allometric growth. The convexity increase slightly with age. In very small specimens (pl. 3, fig. 2), the median septum and the ventral cavities are found in the ventral interior. The youngest dorsal interiors (pl. 3, fig. 1) show a strongly developed dorsal foramen and chilidal plates, and the two median septa of the branchial lamellae are always present. In the youngest specimens, the external sculpture is found in the interior. In the dorsal valve the branchial septa seem to be continons with the ribs of the sculpture. In young specimens, the pseudopuncta are arranged in radial rows, which seem to continue into a rib of the external sculpture.

Remarks: S. s. soudleyensis differs from the subspecies *askerensis* and *hadelandica* in having a marginal thickening of the valves, and in having wedge-shaped triangular branchial lamellae instead of oval ones. The sculpture is also more clearly differentiated in the other two subspecies. According to JONES (1928, p. 418), the subspecies *soudleyensis* differs from the typical subspecies in always being smaller, and having a marginal thickening, and in the shape of the branchial lamellae (rounded in *sericea*, triangular in *soudleyensis*), and the size of the ventral muscle impressions which are smaller and shorter in *soudleyensis*.

Distribution: In Norway this subspecies is very common in the Cyclocrinus zone in the Hamar—Nes district, in Toten, and the northern part of Hadeland. Some specimens from the corresponding layers in the Langesund—Gjerpen district might belong to this species, or to *S. ringsakerensis*. The subspecies may probably also be found in the corresponding layers in the Sandsvær—Eiker district, but no interiors are preserved.

In the Ringsaker district it is represented by *S. ringsakerensis*, which is quite similar, and in the Oslo—Asker and Hadeland districts by *S. s. askerensis* and *S. s. hadelandica.*

In Great Britain it is found in the Horderley Sandstone in Shropshire, and probably in N. Wales (JONES 1928, p. 418).

Sowerbyella sericea askerensis subsp. n.

Pl. 6, fig. 5, texstfigs. 11J and 19F.

Type data: The holotype, PMO 66954, is the cast of the interior of a ventral valve from the lower part of zone 4bγ, N. of Hvalstad st. Asker district.

Material: 11 ventral interiors, 4 dorsal ones, and a large number of casts of the exterior of both valves.

Diagnosis: Subspecies of *Sowerbyella sericea* with well differentiated sculpture, slight convexity of the valves, high width/length ratio (more than 3). Ventral muscle impressions short, no marginal thickening of the valves.

Description: A comparatively small species with slightly convex valves and long hinge-line. A specimen of average size in 15 mm wide and 4,5 mm long. The width/length ratio is generally between 3 and 3,5. The sculpture consists of numerous ribs, about 1 mm between each at the margin, and 3—5 fine striae between each rib. The areas are high, and the pseudodeltidium and chilididal plates are developed in the same way as in most Sowerbyellas.

The ventral interior shows small muscle impressions, wide ventral cavities and usually a well developed vascular system. The branching is variable, in some specimens the main vascula send off a number of branches at almost 180° just in front of the muscle impressions, and in others the vascula bifurcates at a smaller angle, and nearer to the margin of the valve.

In the dorsal interior the branchial lamellae are oval in the adults, and wedge-shaped, radially striated in the young ones. The whole interior is covered with coarse pseudopuncta and the chilidal plates and the dorsal foramen are strongly developed. No crenulations are found at the hinge-line.

Remarks: Sowerbyella sericea askerensis resembles *S. s. sericea* as to size and ventral interior, and differs from it in the sculpture, convexity and the more clearly differentiated branchial lamellae in the dorsal valve. It differes from the other subspecies of *S. sericea* as to shape, size, ornamentation, and in having no marginal thickening.

The subspecies of *Sowerbyella sericea* mentioned here differ from one-another as to sculpture, shape, and in having a marginal thickening or not. All these features may be influenced by the environment, obviously *S. s. soudleyensis* which has coarse sculpture, lived in a siltstone environment, while the finely sculptures *S. s. askerensis* and *hadelandica* lived in a calcareous-muddy environment. It might therefore be more correct to regard them as ecological or geographical races rather than subspecies.

Distribution: This subspecies is found in the Asker district, mainly in the upper part of zone 4bγ. No specimens which with certainty can be identified as belonging to this subspecies, have been found in other districts.

Sowerbyella sericea hadelandica subsp. n.

Pl. 4, figs. 7, 7.

Type data: The holotype, PMO 67138, is the cast of a dorsal interior from the Lower Cyclocrinus Beds in a section between Jonsrud and Stensrud in the northern part of Hadeland.

Material: 3 dorsal interiors, 15 ventral ones, more than 50 complete specimens, and a large number of valves and fragments of valves.

Diagnosis: A *Sowerbyella sericea* subspecies with well differentiated sculpture, strongly convex valves, and triangular outline.

Description: Outline rounded triangular, valves strongly convex and high, sculpture consisting of 10—13 ribs with about 7 striae between each. The size and proportions of the specimens are somewhat variable, one specimen is for instance 15 mm wide and 9 mm long, and another 13 mm wide and 11 mm long. The areas meet under a large angle (140—160°), the dorsal one is generally in the plane of junction of the valves.

The interior is similar to that of *S.s. sericea*, with rounded branchial lamellae, and with a long median septum between the ventral muscle impressions.

Remarks: This subspecies differ from the others described here as to outline of the valves, and sculpture, and from *askerensis* in having a long median septum in the ventral valve. See also remarks to the other subspecies.

Distribution: *S. s. hadelandica* is found in the Lower Cyclocrinus Beds in the northern part of Hadeland, where it is very common. Some specimens from the southern part of that district, and from Ringerike, may belong to this subspecies. However, no interiors have been found from these areas. It is worth mentioning that this species externally resemble *Sampo* (*Leptellina*) *oepiki*, and these two occur together in some localities.

Sowerbyella ringsakerensis sp. n.

Pl. 6 figs. 1—4.

Type data: The holotype, PMO 66951, is the cast of a dorsal interior from the Coelosphaeridium beds between Tørud and Bratberg, Ringsaker district.

Material: About 20 casts of the dorsal interior, and 6 of the ventral, and a large number of casts of the exterior.

Diagnosis: A small *Sowerbyella* species with sculpture and interior like that of *S. sericea sericea*, apart from that it has a number of large pseudopuncta, forming nodes along the hinge-line. These decrease in size towards the notothyrium.

Description: An average adult specimen is about 13 mm wide and 7 mm long. The specimens are small, moderately convex with hemicircular to trapezoidal outline.

The interior is largely similar to that of *S. sericea sericea*, with comparatively large muscle impressions and a median septum in the ventral valve, and oval branchial lamellae in the dorsal. Just as in young specimens of *sericea sericea* and in *sericea soudleyensis*, the formation of the branchial lamellae start with two median septa, each forming the medianmost side of the lamellae, which are badly defined and triangular in the young specimens (and in the adults of *S. s. soudleyensis*). Later the lateral borders of the lamellae are formed, but still the median septa are much stronger than the rest of the lamellae. Occationally (pl. 6, fig. 1) a median septum is found between the two ordinary ones. Most probably it is an intervascular septum, dividing the two median vascula. It is not a constant features, and except in young specimens, it is much lower than the branchial septa.

The dorsal foramen seems to be only slightly developed in this species. It is considerably smaller than in *S. sericea.* Instead, the inner surface of the chilidal plates are united with secondary tissue in adult specimens. The foramen appears as a thin furrow in the notothyrial floor.

The denticulation of the hingeline consists of large pseudopunctae, decreasing in size from the cardinal angles towards the notothyrium. They are described on p. 21.

Remarks: This species differ from all other species of the genus in having these nodes on the hinge-line. They are known also from another species, *Sowerbyella* sp. of SCHMIDT (1951, pl. 51, fig. 8). If it was not for the nodes, *S. ringsakerensis* would definitely have been a subspecies of *S. sericea.* It is remarkable that this species is more highly developed when it comes to the structure of the branchial lamellae, than the later *S. s. soudleyensis.*

Distribution: This species is found in the Coelosphaeridium Beds in the Ringsaker district, where it appears to be very common, at least in some localities. A considerable material has been found in the lowest part of the Encrinite Limestone of the Langesund—Gjerpen district. The interiors are not well preserved. They are all of the *S. sericea*-type, but no nodes can be seen. The trapezoidal shape of some of the specimens might indicate that some of them are *S. ringsakerensis.* The horizon is the same as the one with the rich layers with *S. s. soudleyensis* at Mjøsa. Without better material it is impossible to tell which form occurs at Langesund.

Sowerbyella (*?*) sp.

Material: About 15 exteriors of valves, mainly of the ventral ones.

Description: A small species, moderately convex, with sharp cardinal angles. It is much wider than it is long, the largest specimen present being 15 mm wide and 6 mm long. The sculpture consists of fine ribs with 4—7 striae between each. Some distinct concentric rugae are present near the hinge-line, strongest at the umbo. In the ventral valve there is a pair of diverging ridges with a shallow sulcus between them. These ridges are very prominent in some species, and not so marked in others. The interiors are not known.

Remarks: The diverging ridges found in this species distinguish it from all others in the Oslo Region. It is quite similar to *Sowerbyella sublobata* (Reed 1917, pl. 14, figs. 20, 23), but differs as to sculpture and size. As long as the interior is not known there is no reason to give it a separate specific name.

Distribution: In zone 4bγ in the Ringerike district.

Genus *Eoplectodonta* (Kozlowski 1929).

Eoplectodonta acuminata (Holtedahl 1916.

Pl. 3, figs. 6—12, textfigs. 19A and 23.

1916 *Plectambonites trabeata* Lindstr. var. *acuminata* n. var. — Holtedahl pp. 79—80, pl. 14, figs. 6—7.
1916 *Plectambonites* sp. — Holtedahl, p 80, pl. 14, fig. 8.
1917 *Plectambonites sericea* var. *semirugata* n. var. — Reed, p. 884, pl. 15, figs. 18—26.
1928 *Sowerbyella semirugata* (Reed) — Jones, p. 464.
1938 *Sowerbyella sericea* (J. de C. Sowerby) var. nov. *brynensis* — Whittington, pp. 253—255, pl. 11, figs. 6—9.

Type data: The lectotype, chosen here, is PMO 5279, the cast of the exterior of a dorsal valve and both areas. The specimen was figured by Holtedahl (1916, pl. 14, fig. 7) and is figured in this paper, pl. 6, fig. 11. Holtedahl gives 4b as the horizon, and «City of Oslo» as the type locality. A restudy of the labels and the accompaning fauna shows that the specimen come from zone 4bα (associated with *Sampo* (*L.*) *oepiki* and *Steusloffia costata*) and that the type locality is the site of the Royal Palace in Oslo. This locality is not longer accessible and the specimens were probably collected more than 100 years ago, when the Palace was being built.

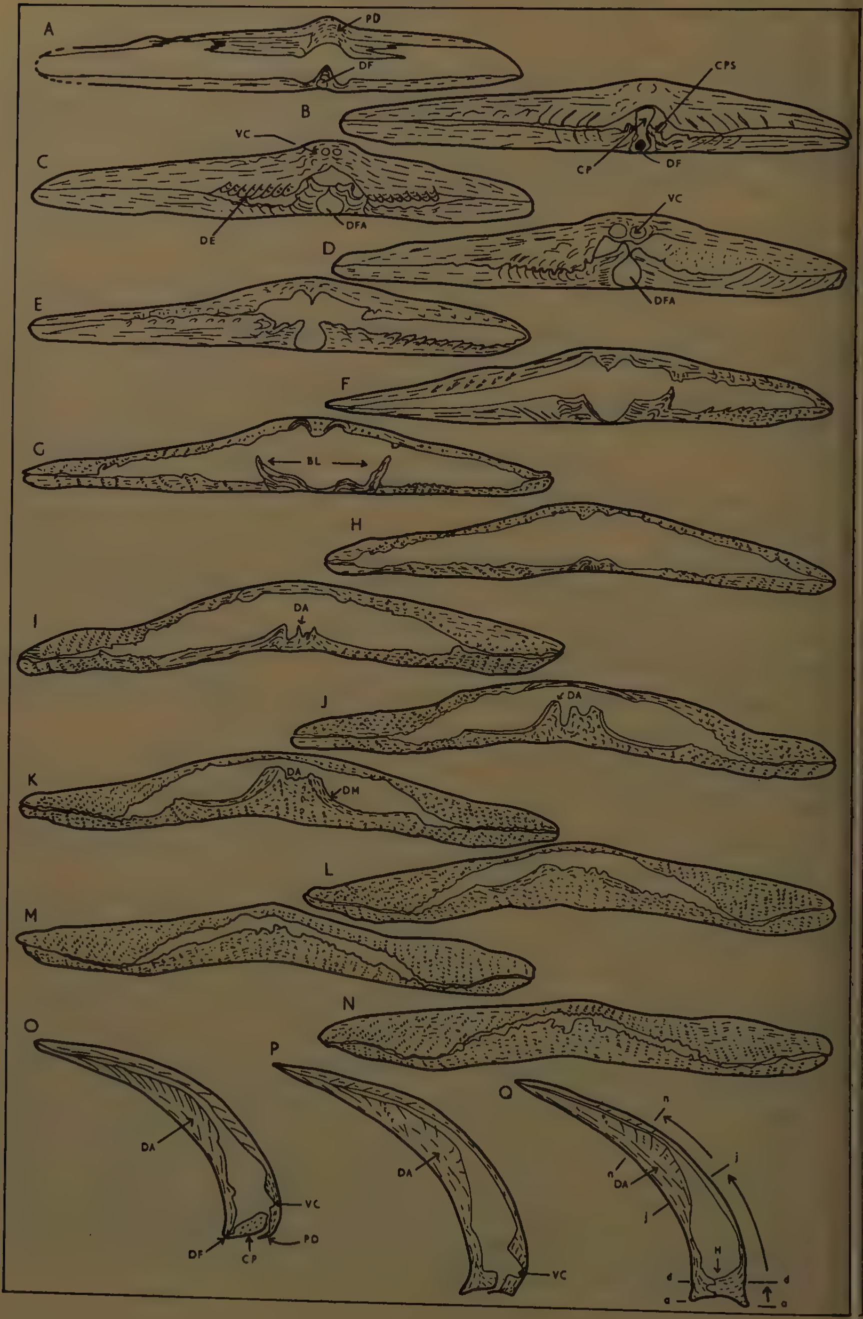
Material: More than 50 ventral interiors, more than 30 dorsal ones, and a very large number of exteriors and complete specimens.

Description: Slightly convex to almost flat species, with sharp cardinal angles. An average specimen is 17 mm wide and 9 mm long. The areas are of about equal size, and the angle between them is 150—120°. The sculpture generally consists of 11—13 ribs with 8—10 striae between each of them. A number of concentric rugae are found, especially near the hinge-line. The strength of the rugation varies. It is found in all specimens, and is prominent and continuous in most of them. In most adult specimens there is a slight marginal thickening of the valves.

The ventral interior has small, rhomboidal muscle impressions, with strong vascular grooves. The large teeth are triangular and broad. The whole surface is pitted with coarse pseudopuncta, and there are short, but very deep ciliar grooves all around the margin (Cg. in pl. 3, fig. 9), each of them corresponding to one of the ribs of the external sculpture. The ventral cavities are thin and deep (textfig. 23 C—D).

The dorsal interior has oval branchial lamellae, with a marked septum. There is no vascular groove as in the Sowerbyellas. The cardinal process is high, the chilidal plates small, and the dorsal foramen large, supported posteriorly by two strong plates. Behind the middle of the branchial lamellae there is a large, high callosity (DA in textfig. 23, I—K, O—Q), which consists of pseudopunctate tissue, which is lined with laminated tissue in the central and anterior part. Owing to this callosity, the branchial lamellae bend forwards, and the effective body volume of the species was extremely small, and the valves very massive. The margins of the branchial lamellae are raised, and in many specimens form high, elevated ridges. In some specimens, mainly in adult ones with a large callosity, the branchial lamellae are depressed into the valves, and are lower than the surface of the valves. This feature is not known from other Sowerbyellinids.

About 2/5 of both the dorsal and ventral hinge-lines are denticulated. The denticules are probably transformed pseudopuncta, and just behind the hinge-line, the strong pseudopuncta are found just to the cardinal angles. Young specimens, where the denticulation is not visible, show in thin sections that there are pseudopunct-like denticulations just below the surface of the hinge-line, even if they cannot be seen on the surface. The denticulations are only clearly visible in fairly old specimens, and in many specimens they can not be seen because of the bad state of preservation. In specimens from silty beds, the denticulations are generally more distinct. This might be due to a selective development of the denticles in that particular environment. On the other hand, specimens from slightly contact metamorphic, hardened rocks always have denticulation, even if the rock was not silty. The selective occurrence of the denticulations is therefore probably due to selective preservation, and not to selective development.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Remarks: E. acuminata differs from most other Eoplectodontas as to sculpture, and being so flat. If differs from the younger species as for instance *E. praecursor*, in the massive valves, and in having a dorsal callosity. The points in which it differs from the closely related and almost contemporaneous *E. karina* are described below.

HOLTEDAHL's material of this species was rather limited, but further studies have shown that it is very common in the Oslo—Asker district. Because of the sculpture, he referred it to *Leptaena trabeata* LINDSTRØM (in ANGELIN & LINDSTRØM 1880, p. 30, pl. 17, figs. 1—4). This species, however, seems to be a *Sampo*, and HOLTEDAHL's variety must be given specific rank. The Scottish species referred to as *Sowerbyella semirugata* (REED) seems to be identical with HOLTEDAHL's species. The author has not studied REED's types, but has seen material from the Balclatchie Beds of the Girvan district, and these cannot be distinguished from the Norwegian specimens. The variety described by WHITTINGTON (1938) of *Sowerbyella sericea* from the Berwyn Hills, also appears to be identical with HOLTEDAHL's species. According to WHITTINGTON, there are no denticulations, but this is probably because of the denticulations of this species is not preserved in casts. Mr. Richard Cave, Cambridge, has kindly informed me that he has found denticulations in some of the specimens, and the author has seen a specimen in Sedgwick Museum, Cambridge, which definitely was denticulated.

Distribution: In Norway this species seems to be restricted to the Oslo—Asker district, where it occurs in the upper part of zone 4b*a*,

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Fig. 23. *Eoplectodonta acuminata* (HOLTEDAHL) A—N 14 transversal sections. The approximate position of the sections are shown in fig. Q, (a—d—j—n). They are, therefore, not parallel. O—Q. 3 longitudinal sections. O. is in the median line of the valves, P. is through one of the ventral cavities, and Q is still further to the side.

The specimens (two different were used, one for figs A—N, and the other, smaller one for figs O—Q) are from the middle part of zone 4b*a*, at Billingstad, Asker district.

Abbreviations: BL = Branchial Lamellae. CP = Cardinal process, CPS = Side branches of cardinal process. DA = Dorsal central callosity. DE = Denticles along the hinge line. DF = Dorsal foramen. DFA = Dorsal foramen with slit in front of cardinal processes. DM = Dorsal muscle impression, or branchial lamellae, fused to DA. H = Hinge. PD = Pseudodeltidium. VC = Ventral cavities.

but does not reach the upper limit of that zone. Specimens from Ringerike and the southern part of Hadeland might belong to this species or to *E. karina*. The exteriors of the specimens are intermediate between the two, and the interiors are unknown or badly preserved.

Apart from the Oslo region, the species is found in the Balclatchie Group in the Girvan district, Scotland, in various districts in North Wales and western England, and in the midlands of Eire (cf. HARPER, 1952, p. 88).

The wide horizontal distribution of this species is remarkable, and coincides with the appearence of other species in the same areas (*Sampo* (*L.*) *oepiki* and *Chonetoidea alpha*).

Eoplectodonta karina sp. n.

Pl. 3, fig. 5.

1916 *Plectambonites quinquecostata* (McCoy) — HOLTEDAHL, p. 78, pl. 15, fig. 9.

Type data: The holotype, PMO 66978, is the interior of a dorsal valve from the uppermost part of zone 4b*α* at the southern end of Nakholmen, Oslo district.

Material: About 20 dorsal interiors, 6 ventral ones, and a large number of exteriors and complete specimens (several hundred).

Diagnosis: Small *Eoplectodonta* species with a dorsal callosity, branchial lamellae with highly elevated boundary ridges, and a very high septum.

Description: Small, hemicircular species (average width 11—12 mm., length 5,5—6 mm). The outline may vary, in some specimens the cardinal angles are right, in others they are about 60°. The convexity is low, slightly stronger than in most specimens of *E. acuminata*. The sculpture also resembles that species, but the concentric rugae are always less prominent in E. *karina*.

The ventral interior is not well known, it has a number (6—8) prominent ridges, and is different from most other Sowerbyellinids, except *E. multiseptata* (WILLIAMS 1955). The ridges are subparalell, not diverging.

The dorsal interior shows high boundary ridges around the branchial lamellae. There is a dorsal callosity, but it is generally less prominent than in *E. acuminata*. The septa in the branchial lamellae are very strong, and are both broad and high. Judging from the thickness of the complete specimens this septum must have touched the ventral valve then the valves were closed, just like the septa of *Christiania.* The septum does not reach the posterior margin of the branchial lamellae as do the vascular grooves found in this position in most Sowerbyellinids. The development in *E. karina* do more resemble that found in *Christiania oblonga* (cf. textfig. 27, 28).

The valves are comparatively thin in this species, and the pseudopuncta appear to be fairly small. The hinge-line shows denticulation, which is of the same type as in *E. acuminata.* Because of the state of preservation it is generally observed in thin sections only. Traces of the denticulation is seen on the left side of the hinge-line of the holotype (pl. 3, fig. 5).

Remarks: E. karina differs from *E. acuminata* as to outline, sculpture, thickness of the valves, development of the branchial lamellae, and in the ventral interior. It is nearly related to *E. multiseptata* (WILLIAMS 1955), from which it differs in having a well developed dorsal foramen, parallel instead of diverging ventral ridges, and in having a denticulated hinge-line. Further studies may show that these two species should be included in a new genus. They show a close resemblance to *Christiania* and *Oepikina,* especially in the development of the branchial lamellae. (textfig. 28).

Distribution: E. karina is found in the uppermost part (4–5 m) of zone 4b*a* in the Oslo—Asker district. In some localities it might possibly be found also in the lowest beds of zone 4b*β*. As mentioned above, some specimens found in the Ringerike and Hadeland districts in corresponding horizons, might belong to this species or *E. acuminata.*

Eoplectodonta (?) *percedens* (HOLTEDAHL 1916).

Pl. 4, fig. 9, pl. 6, fig. 7, textfig. 19H.

1916 *Plectambonites Schmidti* TQU. var. *percedens* n. var. — HOLTEDAHL, pp. 81—82, pl. 15, figs. 10—11.

1928 ? *Sowerbyella rhombica* var. *conspicua* (REED) — JONES, pp. 508—509.

Type data: The lectotype, chosen here, is PMO LO132, the specimen figured by HOLTEDAHL, pl. 15, fig. 10 (this paper pl. 6, fig. 7), the exterior of a ventral valve from zone *4b* (probably the uppermost part of 4b*a* or the lower part of 4b*β*) at Bratterud, Ringerike district.

Material: 4 ventral interiors, and about 20 exteriors.

Description: A strongly convex, rather large species. The width is between 22 and 25 mm, and the length between 13 and 15 mm in average adult specmens. The sculpture consists of a small number of fine ribs, with 6–7 striae between each of them. The areas form an angle of about 90° in adult specimens, and the apexes, especially that of the ventral valve, are bent over the areas.

The dorsal interior is unknown.

The ventral interior has small, angular muscle impressions, divided into unequal parts by the broad vascular grooves. Just in front of the muscle impressions the vascula widen, and become nearly as broad as the muscles. The ventral cavities are comparatively shallow, and wide. The inner surface of the valve has extremely long ciliar grooves, a feature which seem to be characteristic for this species and *E.* (?) *rhombica.* In adult specimens about 3/4 of the hinge-line is finely denticulated. In the present material the denticulation can only clearly be seen in one specimen. The other three ventral interiors are either badly preserved, or so small that they cannot be expected to show denticulation.

The shell substance is coarsely pseudopunctate.

Both *percedens* and *rhombica* have a peculiar type of denticulation. About 1/3 of the hingeline show denticules increasing in size from the denthyrium. The lateral parts of the hinge-line show smaller denticles, which are all of uniform size.

Remarks: This species was first described by HOLTEDAHL (1916). Judging from the exterior of the specimens figured by HOLTEDAHL, JONES (1928, pp. 508—509) was of the opinion that the species might be related to *Sowerbyella rhombica* var. *conspicua* (REED 1917). The author is inclined to believe that the form described from Gelli Grin by JONES (l.c.pl. 22, figs 3—4) is not identical with that described by REED (1917) from the Girvan district. The vascular system in the Welsh form has many, distinct and irregularly branching vascula, resembling the impressions of a *Sampo*, whereas the vascular system is only slightly developed in the Scottish form. Both differ from the Norwegian specimens in not having long ciliar grooves and also in sculpture and size (the Scottish form). The author is therefore inclined to believe that all three forms are separate species, at least until the dorsal interior of *percedens* is better known. The species differs from *rhombica*, as defined here, as to size and sculpture and the smaller ventral muscle impressions. Both these species are included in *Eoplectodonta*, but it is questionable whether this is correct as they appear to be related to *Sowerbyella*. The two species resemble the others referred to *Eoplectodonta* both in the muscle impressions being of a rhomboidal shape, and in having prominent ciliar grooves.

Distribution: HOLTEDAHL (1916) reports this species from the zones 4bα and 4bβ. The author's studies show that *E.* (?) *percedens* is confined to the uppermost part of zone 4bα, and to 4bβ. In the lowest part of 4bγ, there are some specimens which might belong to this species.

It is recorded from the Oslo—Asker, Ringerike and Langesund—Gjerpen districts. JONES (1928, p. 509) records this species from the Mjøsa district. However, there are no specimens from that district in the material at the authors disposal.

Eoplectodonta (?) *rhombica* (McCOY 1852).

Pl. 4, figs. 2—3, textfig. 19C.

1916 *Plectambonites sericea* var. *rhombica* (McCOY) — HOLTEDAHL, pp. 80—81, non pl. 14, figs. 4—5 = *Sowerbyella* cf. *thraivensis* (REED 1917).

1928 *Sowerbyella rhombica* (McCOY) — JONES, pp. 426—430, pl. 22, fig. 1. See this paper for further references and discussion.

Material: One ventral interior, two complete specimens, and a number of fragmentary exteriors.

Description: Moderately convex species with hemicircular to rounded triangular outline. Valves large, an average specimen is 32 mm wide and 19 mm long. Sculpture consisting of closely placed, sharp ribs with 3—5 prominent striae between each. Areas high, delthyrium and notothyrium broad.

The dorsal interior is not known in the Norwegian material.

The ventral interior has small, rhomboidal muscle impressions, broad vascula, and strong, broad and rather shallow ventral cavities. At least 3/4 of the hingeline is crenulated with denticles of the same type as found in *E.*(?) *percedens*. The internal surface is striated, and pitted with pseudopuncta arranged in radial rows. There are ciliar grooves which are not so long as in *E.* (?) *percedens*, and not so strong as in *E. acuminata*.

Remarks: This species differs from all other Norwegian Eoplectodontas and Sowerbyellas in size and ornamentation. It seems to be closely related to *E* (?) *percedens*, and together with that species it forms an intermediate group between *Sowerbyella* and *Eoplectodonta*.

The species *rhombica* is not well defined, and the interior is not known in the type material. There is therefore a possibility of the Norwegian material belonging to another species. It resembles the type in size and ornamentation. The convexity is slightly stronger in the type than in the specimens described here. According to JONES (1928, p. 428), the only specimen from Cynwyd of which the interior is known and which can be referred to this species have a structure similar to that of «*Sowerbyella rhombica* var. *conspicua* from Gelli Grin. As mentioned above, this species does not differ much from *E.* (?) *percedens* except for the vascular system. The present material is therefore, at least at provisionally included in *E.* (?) *rhombica*.

Distribution: The Norwegian specimens are found in zone 4bδ, probably mainly the upper part of that zone, in the Oslo—Asker district, and in the southern part of the Hadeland district, near Grindvoll.

Genus *Chonetoidea* JONES 1928.

cf. textfig. 24.

A number of species from the Middle Ordovician of the Oslo region is included in this genus. A distinct trend of evolution can be followed in the species described here, from *C. stoermeri* with large, regular branchial lamellae over *C. alpha* with smaller, triangular ones, and over *C. gamma* with regular small arches, and strong spines also outside the lamellae, to the typical Upper Ordovician species *C. papillosa* (REED) and *C. iduna* ÖPIK (1933), which have small indistinct branchial arches, and numerous spines on the rest of the surface (textfig. 24).

It is therefore necessary to alter the diagnosis of *Chonetoidea* so that it will include species with differentiated sculpture (*C. gamma*) and species with regular branchial arches (*C. stoermeri* and *C. alpha*). The ventral interiors are generally also more strongly developed in the older species, and especially the muscle impressions can be seen more clearly, also posteriorly.

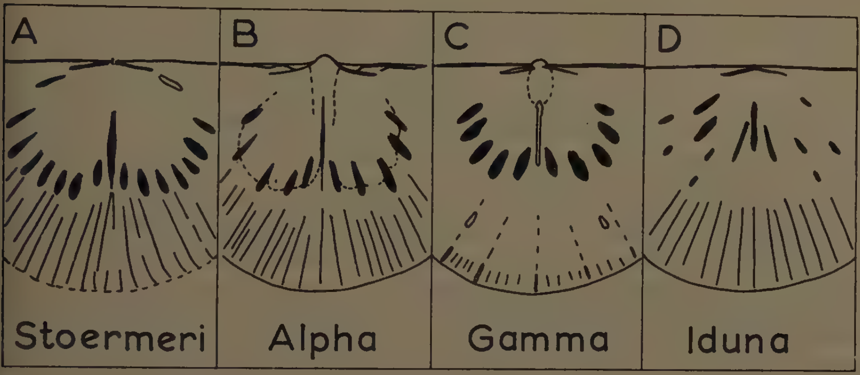

Fig. 24. The dorsal interior of some species of *Chonetoidea*. A. C. *stoermeri* sp. n. from zone 4aα_3 in the Asker district. B, C. *alpha* sp. n. from zone 4bα, at Billingstad, Asker district. C, C. *gamma* sp. n. from zone 4bγ, at Blakstad Road Junction, Asker district. D, C. *iduna* ÖPIK 1933, from zone 4cα, of *Tretaspis seticornis*, from just South of Billingstad railway station. The figures are drawn from casts, they are reduced to the same size, and are magnified about 7 times.

Because of the prominent ventral cavities (cf. pl. 2, figs. 21—22) found in *Chonetoidea*, this genus is included in the subfamily Sowerbyellinae though there is some doubt as to whether this is correct. Especially in the structure of the branchial arches (corresponding to the branchial lamellae) it shows a resemblance to the Leptestinae.

Chonetoidea can be distinguished from *Aegiria* ÖPIK (1933) because of the distinct branchial lamellae in the latter genus, but otherwise they are quite similar. Formerly it was believed that only *Aegiria*, and not *Chonetoidea* had a median septum. It is, however, found in most specimens belonging to the older species. This is also the case with the strongly developed muscle impressions. HAVLICEK (1952) has described some species, which seem to be intermediate between *Chonetoidea* and *Aegiria*.

Sericeoidea LINDSTRÖM (1952) is definitely closely related to *Chonetoidea*, but lack the well defined branchial arches. It is still doubtful whether the three Middle Ordovician species described here should be referred to *Chonetoidea*, or to *Sericeoidea*. WILLIAMS (1955) referred his species *abdita*, which is rather like *C. alpha* to *Sericeoidea*. In this case it would not be necessary to alter the diagnosis of *Chonetoidea*.

Chonetoidea gamma sp. n.

Pl. 2, figs. 12—13, textfig. 24C.

Type data: The holotype, PMO 66988, is the cast of a dorsal interior from the middle part of zone 4bγ at Blakstad Road junction, Asker district.

Material: About 75 casts of interiors and exteriors of both valves, and a small number of fragmentary valves.

Diagnosis: Chonetoidea species with strong ventral muscle impressions, small, regular branchial arches with some few spines in the marginal parts of the dorsal interior, and a differentiated sculpture.

Description: Small, flatly planoconvex species with right or slightly less than right cardinal angles. Sculpture consisting of numerous fine ribs with 3—5 striae between each at the margin. The holotype is 7 mm wide and 5 mm long, and is a specimen of average size in the Oslo—Asker district. Those from the Hadeland district are often considerably larger, up to 10 mm wide.

The dorsal interior has small, rounded branchial arches, and in most specimens there are also some spines in the marginal areas of the dorsal interior (cf. pl. 2, fig. 13). The spines are believed to be homologous with the pseudopuncta. In thin sections one can see that they are of the same histological structure. The spines of the branchial arches are directed inwards against the centra of the arches, and not as those in the branchial lamellae of *Leptelloidea* (s.l.), towards the margin of the valves. The ordinary pseudopuncta, which are abundant in this species, are much smaller than the spines.

The socket plates are strong, and long, diverging at about 150°. The cardinal processes are not clearly visible in the dorsal interiors, but judging from what can be seen in casts of the areas, they are similar to those of *Sowerbyella*.

In the ventral interiors, the muscle impressions can be seen quite clearly, also posteriorly. They are comparatively small in this species.

Remarks: As mentioned above, *C. gamma* differs from the younger species of *Chonetoidea* in having distinct ventral muscle impressions, regular branchial arches, and in the differentiated sculpture. There are, however a number of the Chonetoideas where the sculpture is undifferentiated on the exterior of the valve, which show indications of differentiation in the interior, where the sculpture usually is visible to the branchial arches. *Gamma* differs from *stoermeri* and *alpha* as to the sculpture, in having smaller branchial arches, and occational spines outside the arches in the dorsal interior.

Distribution: This species is found at the type locality, in the railway section between Billingstad and Hvalstad in Asker, and at Grefsen and Nakholmen in the Oslo district. At all localities it is found in zone 4bγ, generally in the middle part of the zone. It appears to be relatively most abundant in localities where the facies is euxinic (Grefsen, Nakholmen) or intermediate between euxinic and ventilated (Blakstad). It also occur in the Cyclocrinus Shale (layer B of KIÆR 1926, p. 5) at Tønnerudodden, Hadeland district. This species might also occur in other districts, from which no interiors are known. It is usually referred to as «young specimens» of *Sowerbyella*, because of the resemblance as to shape and size. The specimens from Hadeland are slightly larger than the typical ones, and come from beds with a ventilated facies.

Chonetoidea alpha sp. n.

Pl. 2, figs. 20—22, textfig. 24B.

Type data: The holotype, PMO 67027, is a natural cast of a dorsal interior from zone 4bα, about 8 m below 4bβ, in the roof of the second tunnel W. of Billingstad st. Asker district.

Material: About 30 casts of the dorsal interior, 18 of the ventral, and a large number of casts of exteriors.

Diagnosis: *Chonetoidea* species with undifferentiated sculpture, no spines outside the subtriangular branchial lamellae and with a median septum.

Description: Small planoconvex to unequally biconvex specimens with right cardinal angles. Sculpture consisting of numerous equal or subequal ribs. In a few cases every third or fourth rib is slightly more prominent than the others. The areas are comparatively high. A specimen of average size is 6—7 mm wide and 2,5—3,5 mm long.

The dorsal interior is similar to that of *C. gamma*, except for the branchial lamellae being more triangular in outline, especially in old specimens. There is always a medium septum, which generally is prominent. In some specimens it is double.

The ventral interior is like that of *C. gamma* and *Aegiria*, with two prominent muscle impressions, and ventral cavities.

Remarks: This species differs from *C. gamma* in the undifferentiated sculpture, and the shape of the branchial lamellae, and from *C. stoermeri* in having smaller branchial lamellae composed of fewer spines. It differs from *C. iduna* and *C papillosa* in not having any spines outside the branchial lamellae, and in the more regular outline of the latter, and in the distinct muscular impressions in the ventral interior. It differs from *Sericoidea* in having well developed branchial lamellae.

It differs from *Sericoidea* (?) *abdita* WILLIAMS (1955) in having more spines in the branchial lamellae (5—6 instead of 3), and in the undifferentiated sculpture.

Distribution: It is found in zone 4bα, upper part. Very common in the northern part of the Asker district. Sporadic in the rest of that district, and in Oslo.

Chonetoidea stoermeri sp.

Textfig. 24A.

Type data: The holotype is a natural cast of a dorsal interior from zone 4aα$_3$, of *Ogygiocaris dilatata sarsi* and *Glossograptus hincksi*, in a road section 500 m N. of Dalbø Road junction, on the road between Bø and Heggedal in Røyken, Asker district.

Material: About 25 casts of the exterior and interior of both valves.

Diagnosis: *Chonetoidea* species with coarse, undifferentiated sculpture, no spines outside the large branchial lamellae, which are composed of 7—9 pairs of spines.

Description: Small, thin-shelled, planoconvex species with right, or slightly less than right cardinal angles. An average specimen seems to be about 8 mm wide and 3,5—4 mm long. It is difficult to give exact measurements for this species, because all specimens occur crowded on small spots, where they overlap.

Sculpture consisting of subequal coarse ribs. Ventral interior similar to those of *C. gamma* and *C. alpha*, but generally less calcified. Dorsal interior with large branchial lamellae, composed of 7—9 pairs of spines. No spines are found outside the lamellae. Shell structure unknown.

Remarks: This species is the oldest one of the genus. It differs from all younger ones in having very large branchial lamellae, and from *Sericoidea* in the stronger and more numerous spines in the branchial lamellae. The ventral interior is similar to that of *Sericoidea*, *C. gamma* and *C. alpha*.

Distribution: Interiors of this species are found only in the type-locality, and a few other localities in the Røyken facies of zone 4aα. It is, however, very difficult to distinguish this species from *Alwynella ildjernensis* if the interiors of the specimens are not known. The size, shape and sculpture of the two species are remarkably alike, and they partly occur in the same layers. It may therefore be possible that *C. stoermeri* also occurs outside the Røyken district.

Family Christianidae WILLIAMS 1953.

As mentioned above (p. 37), this family is tentatively included in the Plectambonitacea, (near the Leptestidae) because of the new observations on the ontogeny, and the structure of the cardinalia in *Christiania oblonga* (PANDER 1830).

Genus *Christiania* HALL & CLARKE 1892.

Type species: Leptaena subquadrata HALL 1883, Middle Ordovician of Tennessee.

A number of species of *Christiania* have been described, but only three or four of them are well known. In Norway a common Middle Ordovician species was called *Ch. tenuicincta* (McCOY). There is, however, some difficulty as to the taxonomy of this name. McCOY used the specific name *tenuicincta* for two different species, *Producta tenuicincta* McCOY 1846, and *Leptaena tenuicincta* McCOY 1849. McCOY himself (1852, p. 239) stressed the fact that the two species were different. The first species (from the Kildare Limestone in Eire) is not well known, and it can hardly be regarded as a valid species, at least not before the types have been restudied. *Leptaena tenuicincta* is from the Bala rocks of Wales. It is generally (DAVIDSON, HOLTEDAHL a. o.) regarded as a synonym of *Producta tenuicincta*, and is usually referred to as *Christiania tenuicincta*. The author had the opportunity of studying the types of *L. tenuicincta*, and discovered that it is a *Sowerbyella*, probably of the *sericea*-type. The figured specimen is a fragmentary cast of the exterior of a specimen, where both sides are broken off. The artificial cast, made from sealing wax which was used by McCoy, was unable to «take» the sculpture and the finer details of the hinge-line, and the species was therefore described as smooth. Both the sculpture, fine ribs and striae, and the hinge-line structure is like that of *Sowerbyella sericea.* The specimen as well as the original artificial cast are preserved in the Sedgwick Museum, Cambridge.

The author prefers to regard *Leptaena tenuicincta* McCoy as a synonym of *Sowerbyella sericea*, and *Producta tenuicincta* as a nomen dubium for the time being, until the types of the latter have been restudied.

This will mean that the *Christiania* species, which up to now have been called *Christiania tenuicincta* (McCoy) will have to have a new name.

Christiania holtedahli nom. nov.

Pl. 5, figs. 1—11, 15—16, Pl. 6, fig. 10, textfigs. 12L, 25, 26A, 27B, 28C, 29—31

1916 *Christiania tenuicincta* (McCoy)—Holtedahl, pp. 85—86, pl. 16, figs. 4—8.

Type data: The holotype, PMO L 0071, is the cast of a ventral interior from zone 4bα at Bratterud, Ringerike district. The specimen was figured by Holtedahl, (1916, pl. 16, fig. 7).

Material: A large number of complete specimens and casts of separate valves, and some free specimens, from several localities in the Oslo region. From at least three localities, the number of specimens exeed 200.

Diagnosis: Christiania species with small, bifid cardinal processes, diagonal branchial septum ancylosed both to the lateral and central branchial septa, forming a transverse septum between them. The socket plates are thin and ancylosed to the lateral branchial septa. The median septum is thin, and weakly developed in most specimens. The valves are pseudopunctate mainly in their lateral parts.

Description.

Exterior: Generally this species is elongate and strongly curved. In the anterior part the central portion is globose, while the corners of the hinge-line are nearly flat. These triangular, flat corners are often broken, and it is therefore often difficult to evaluate the variations in width. Posteriorly the valves flatten out, and are generally slightly broader than the hinge-line.

The convexity of the ventral valve is strongest near the apex, and gradually fades out posteriorly (Cf. textfig. 26A). The dorsal valve is rather flat near the hinge-line, at least in the central parts, and the convexity appears later in the development often starting as a slight geniculation. At the margin, the two valves are parallel. This indicates that the young valves were rather flat, especially the dorsal one, and that the convexity appeared in a later period of growth, together with a rapid increase in body-volume.

The dimensions of the specimens can be seen in textfig. 29, and the variation in size is discussed above (p. 54).

The ornamentation of the surface consists of fine concentric lines, which sometimes are accenturated by weathering. There are no radial striae. Just behind the cardinal processes, in the dorsal valve, there is a small node, the structure and purpose of which are discussed below. There is a pedicle foramen just above the apex of the ventral area.

Dorsal interior: Dorsal area narrow, almost rectangular. The angle between the areas is 120—150° in young specimens, decreasing to less than 90° in gerontic ones.

Cardinal processes double, very small in adult specimens, and relatively more prominent in the younger ones. The sockets are remarkably small, and in a few specimens there are also traces of an additional pair of sockets, nearer to the cardinal processes.

The branchial lamellae consist of two elongated loops cemented to the valve. Each lamella has a transverse septum. These transversal septa divide the branchial loops into two parts, a large posterior, and a smaller anterior one. The ontogenetic development of the branchial lamellae is discusse below.

There is a certain amount of variation in the development of the branchial lamellae. The central pair of septa (cb)[1] are subparallel, and rather uniform. Between them one usually finds a median septum (ms), particularly well developed in old specimens. The lateral branchial septa (lb) are in most cases ancylosed to the socket plates (sp.). In most specimens they are continuous, but in others, a distinct

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[1] The abreviations used for the septa, refer to the corresponding terms in textfigs. 27 end 28.

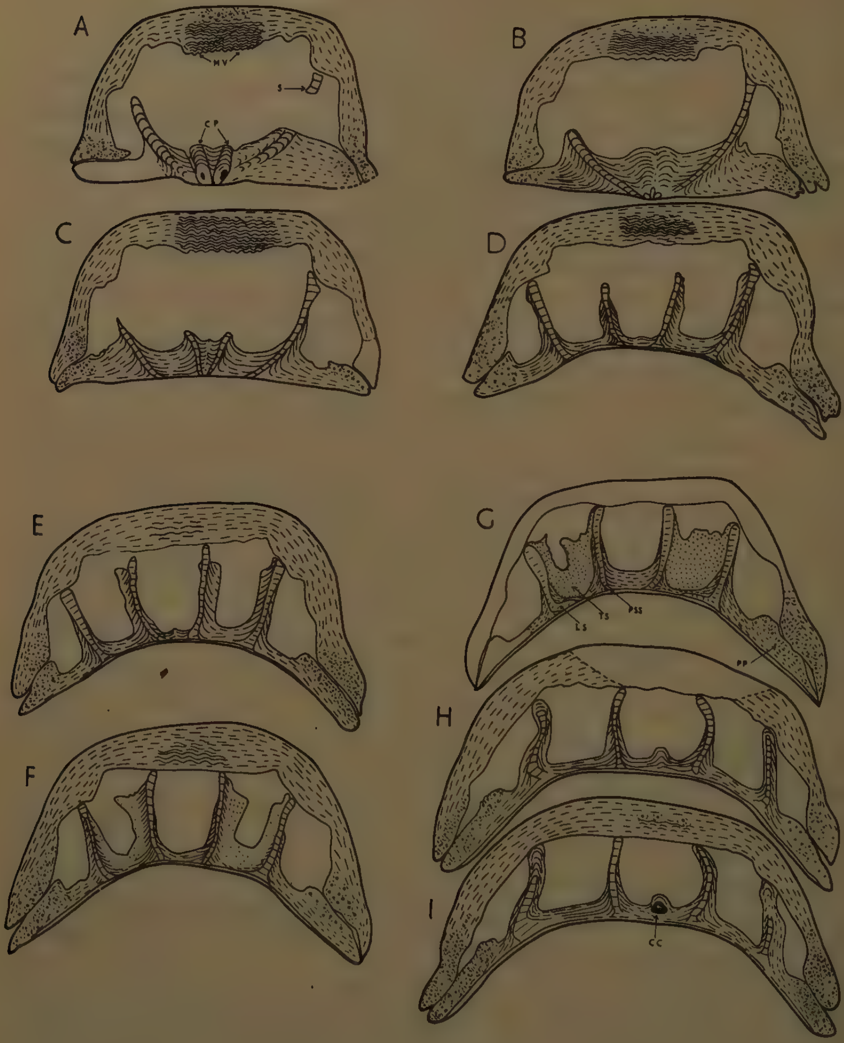


Fig. 25. *Christiania holtedahli.* Nine parallel thin sections (peels) through a specimen from the upper part of zone 4bα at Billingstad, Asker district. A. is nearest to the hinge-line.

Abbreviations: CC = Central body of median septum. CP = Cardinal processes. LS = Lateral branchial septum. MV = Impressions of vascula ? PP = Pseudopuncta. PSS = Central branchial septum. S = Septum, probably a part of the lateral branchial septum. TS = Transverse septum.

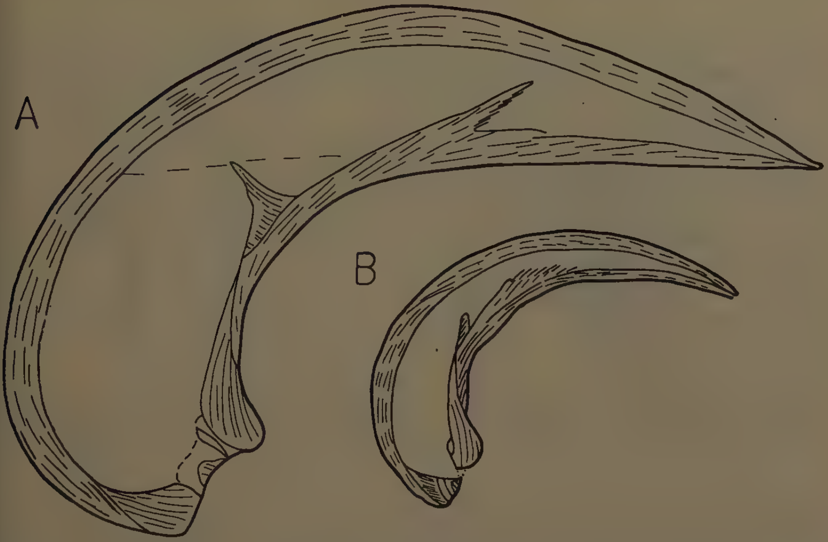


Fig. 26. *Christiania.* Longitudinal sections of *A. Ch. holtedahli* from the upper part of zone 4bα at Billingstad, Asker district. 7x. B. *Christiania oblonga* (PANDER) from the Lower Ordovician at Popovka, near Leningrad. 7x.

angle is observed at the point of coalescense. In the young specimens (pl. 5, fig. 2) they do not touch at all.

Posteriorly the lateral and central branchial septa join to form the elongated branchial loops. In a few specimens (pl. 5, fig. 15) the lateral septa seem to meet behind the central ones, without being connected with them. This may be due to the strong development of a concentric ridge, joining the lateral septa. Even if this is the case, the posterior part of the branchial loops in those specimens are less developed than usual. This is the case with one of the largest specimens known from the Oslo region.

The transverse branchial septum is a striking feature in all species of *Christiania.* In *Ch. holtedahli* they form a concave ridge, which is only slightly developed in the young specimens, but almost of the same strength as the other septa in adults. In this species it is difficult to homologize the structure with those of other brachiopods. In *Ch. oblonga* (PANDER), a more primitive species, these structures are differently developed, and here it is not so difficult to explain the formation of the transverse septa (cf. textfig. 27 and 28).

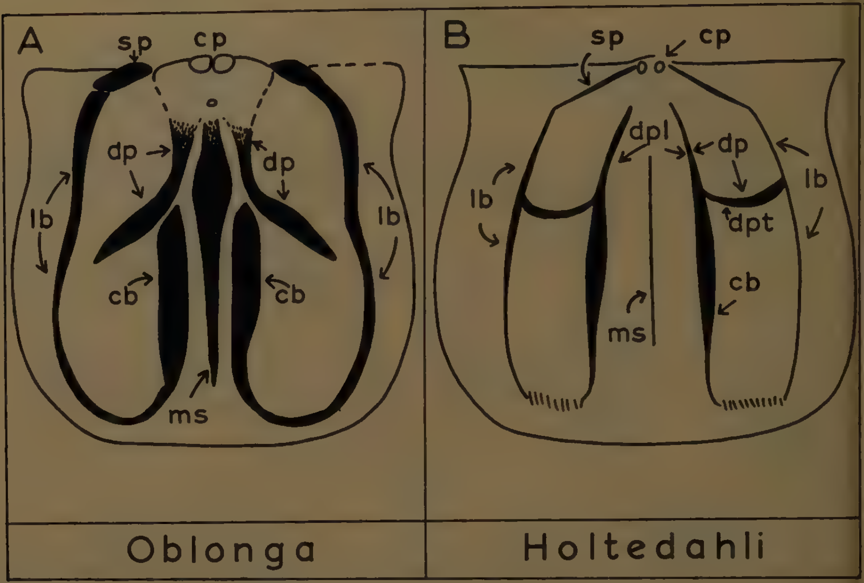


Fig. 27. Diagramatic figures of the dorsal interior of *Christiania oblonga* (PANDER 1830), from zone B3 at Popowka near Leningrad, (A) and *Christiania holtedahli*, from zone 4b*a*, at Blakstad, Asker district, Norway. The figures are reduced to the same size, A is magnified about 10,5 times, and B is magnified about 6,5 times.

Abbreviations: cb- central branch of branchial loop. *dp* — diagonal septum. *dpl.* — longitudinal part of diagonal septum. *dpt.* — transversal part of diagonal septum. *cp* — cardinal processes. *lb* — lateral branches of branchial loop. *ms* — median septum. *sp* — socket plates.

In *Ch. oblonga* the lateral branchial septa are connected with the socket plates, just as in *Ch. holtedahli.* The central branchial septa are, however, formed by two elements, the first of which is the posterior part of the central septa. The second element consists of a pair of diverging septa, commencing just behind the cardinal processes, and terminating where the transverse septa are found in *Ch. holtedahli* and *Ch. subquadrata.* At this point the septa are strongly swollen, but they are not, or at least generally not fused to the central septa, and never to the lateral ones.

It is therefore very probable that the central and transversal septa in *Ch. holtedahli* also consist of two elements, one (dp) forming

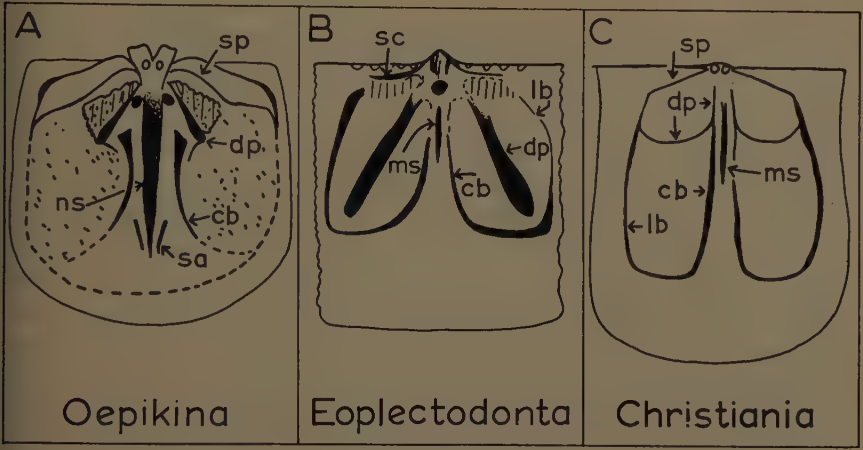


Fig. 28. The dorsal interiors of *Oepikina*, *Eoplectodonta* and *Christiania*, to show the development of the branchial septa. A. *Oepikina dorsata* (BEKKER) from zone C2 in Esthonia. B. *Eoplectodonta karina* sp. n. from zone 4bα in the Oslo district. C. *Christiania holtedahli* sp. n. from zone 4bα in the Asker district *Abbreviations:* cb — central branch of branchial loop. dp — Diagonal septum. lb—lateral branch of branchial loop. ma—muscle attachments. ms —median septum. sa — intervascular septa. sp. — socket plates.

the anterior part of the central septum and the transversal septum, and the other (cb proper), forming the posterior part of the central septum.

This interpretation of the structure of the branchial lamellae of *Christiania*, makes it possible to homologize them with those of some of the Sowerbyellinids, as for instance *Plectodonta*, *Eoplectodonta*, and the *quinquecostata*-group of *Sowerbyella* (cf. textfig. 28).

In *Ch. subquadrata*, the transversal septum and the anterior part of the central septum are distinctly lower than the other septa, thus confirming the interpretation of the development of the septa given above.

Ventral interior: The triangular ventral area is comparatively high. Teeth strong, with oblique supporting plates.

The muscle impressions are subovate, and are not well limited posteriorly. In adult specimens, they continue into two semiparallel vascular grooves. The distance between the branchial lamellae and the interior surface of the ventral valve is less than 0,1 mm, and they

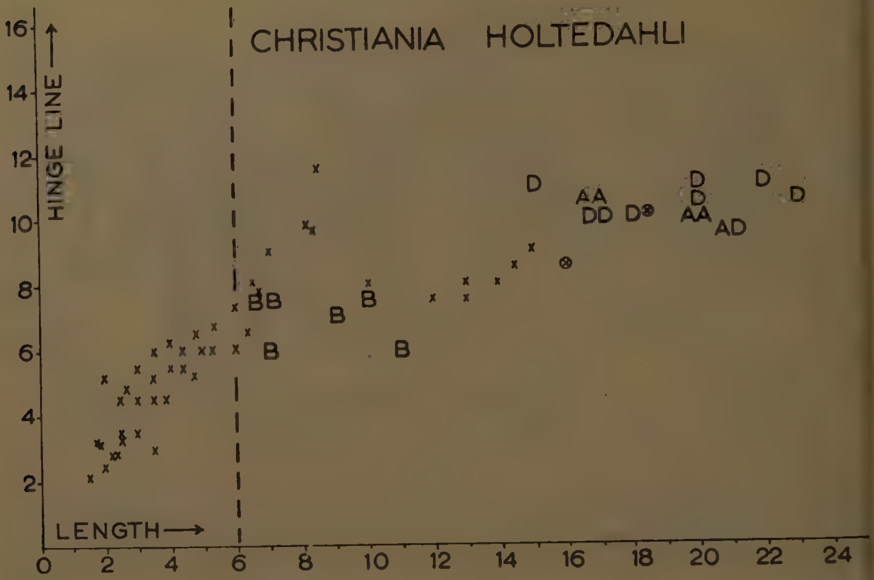


Fig. 29. Diagram showing the variation of the size in *Christiania holtedahli* sp. n. from various populations in the Oslo Region. x. are specimens from the typical populations, Billingstad and Blakstad in the Asker district. ⊕ are two large specimens found together with the typical ones. B. are small specimens from the lower part of sone 4bα at Gomnes, Ringerike district, probably intermediate between *Ch. holtedahli* and *Ch. elongata*. (cf. textfig. 31). A. are specimens from the Bratterud population (upper part of zone 4bα, and possibly lowest part of zone 4bβ). D. are specimens from the Coelosphaeridium Beds (?) of the Toten district. The broken line at 6 mm length, is the arbitary border between the larval and adult specimens in the Billingstad and Blakstad populations.

therefore divide the interior of the animal in five unequal parts, one central, two «interbranchial», and two lateral ones (cf. textfig. 25). The central and the lateral parts are longitudinally striated in the ventral valve. In the depressed «interbranchial» areas the main vascula are found (cf. p. 36, textfig. 12LM).

In young specimens, the branchial grooves are not developed, and the muscle impressions are well limited posteriorly.

The pseudodeltidium is found in all specimens with a supraapical foramen. The development varies considerably in specimens of the same size. Even very large specimens may have a small pseudodeltidium, and small specimens may have a comparatively large one. Gerontic specimens, however, always have a large one. The pseudodeltidium is built as a triangular to rectangular pyramid, consisting of horizontal lamellae. The surface of the lamellae is smooth inwards, and outwards (in the delthyrial opening) they are long and pointed, so that the cross-section of the pseudodeltidium is like a saw-blade. The lamellae seem to be continuous with the growthlines of the area, with which they are intimately connected. In the gerontic specimens the pseudodeltidium reaches almost to the cardinal processes.

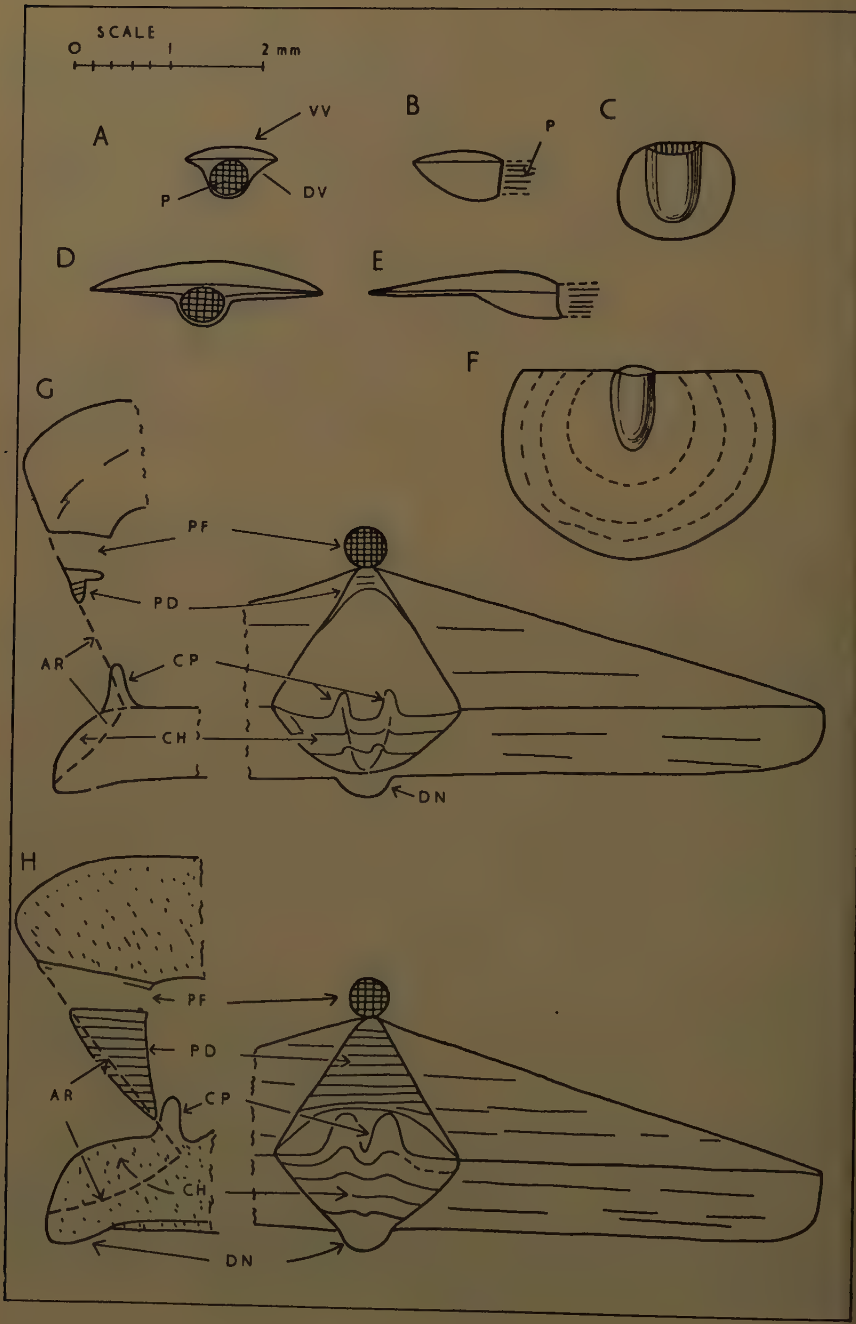
The chilidium seems to be continuous with the cardinal processes, and has very strong growth-lines, the edges of which in some cases are turned upwards, against the pseudodeltidium. Also in the chilidium, the growth-lines seem to be continuous with those of the area. It is also interesting to note that the notothyrium is elliptical to hemicircular, and not triangular such as the delthyrium.

Structure of the shell: The author has seen typical strophomenid puncta in all sectioned valves of *Christiania holtedahli* (cf. textfig. 25). In contrast to most other Strophomenids, this species has pseudopuncta which are almost parallel to the surface of the valves. They are restricted to lateral and centromarginal parts of the ventral valves. In the dorsal one, they are only found along the margin. The fine striation in the central parts of the ventral valves, may be due to vascula (textfig. 25, mv, and pl. 5, fig. 10). In tangential sections of the valves, the puncta are cut longitudinally. The strongly inlined pits of the puncta can be seen on most casts of the ventral interior (pl. 5, fig. 16).

Boring organisms are observed in many specimens as fine threads penetrating the shell, especially at the umbo. Probably this is a post mortem feature, but it is mentioned here as it seems to be more common in this species, than in other brachiopod species from the same localities.

Ontogeny: Larval valves are found abundantly from two localities, and a continuous series from very small to adult specimens are present (pl. 5, figs. 1—9, cf. textfig. 29). The development of the dorsal interior has been studied in detail.

In specimens 6—7 mm wide and 6 mm long, the transversal branchial septum is not developed, and the lateral and central septa are not united into loops. In still smaller specimens, the branchial septa are diverging, not subparallel, and the lateral ones can clearly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be distinguished from the socket plates. In specimens less than 5 mm wide (4 mm long) the cardinal processes are fused to the socket plates. In still younger specimens they are nodes on the proximal end of the socket plates, and in the youngest specimens, there is no cardinal process at all.

In all young dorsal interiors, there is a longitudinal groove with hemicylindrical bottom, tapering towards the area. This groove, which is supposed to be the pedicle groove, is of the same size in all specimens (0,3—0,4 mm). It is therefore more prominent in the smaller specimens than in the larger ones. It is also remarkable that the groove has the same diameter as the pedicle foramen in the ventral valve of the adult specimens. Some specimens showing the area of the dorsal valve, indicate that the groove really terminated in a foramen, which in most specimens was placed in the dorsal valve, even if it in the larger ones also invaded the ventral area. External impressions of some very small dorsal valves, indicates that in these specimens, the whole of the supposed pedicle foramen was in the dorsal valve (text-fig. 30 A—C). The presence of branchial septa and socket plates, and of associated ventral valves, indicates that the valve in which the pedicle foramen is found, really is the dorsal one.

All these facts points towards the pedicle of *Christiania holtedahli* being in the dorsal valve in the young larvae, and migrating during the ontogeny into the ventral valve, where it in the adult specimens passed through a supraapical foramen. It is remarkable that it was of the same size both in the larvae and adults. This may indicate that the larvae lived in a vertical position, with the areas down, fixed to the bottom with the pedicle. Later, they turned over, and rested on the ventral valve.

Fig. 30. *Christiania holtedahli sp. n.* A—C very small larva seen from the area (A), the side (B) and the dorsal valve (C). D—F. A larger larva seen from the area (D) the side (E), and the dorsal valve (F). G. Section through the median line, and areal view of a young, adult specimens. H. Similar views of a gerontic specimen. All the figures are semidiagramatic, and based on several specimens from the same population in the upper part of zone 4bα at Blakstad, Asker district.

Abbreviations: AR = Projection of area into the sections. CH = Chilidium. CP = Cardinal process. DN = Dorsal node (pedicle scar?) DV = Dorsal valve. P = Pedicle, and pedicle foramen. PD = Pseudodeltidium. PF = Pedicle foramen. VV = Ventral valve.

The outline of the larval specimens was, during the later part of the ontogeny, rounded quadratic, with right cardinal angles, and with about the same width and length. The convexity was considerably smaller than in the adults. In the youngest valves, the outline was more circular, the hinge-line being smaller than the maximum width of the specimens (pl. 5, fig. 7). Judging from the growth-lines in the smallest specimens, this tendency was stronger in the still smaller larvae, which seem to have been almost perfectly circular, with only a large foramen in the dorsal valve (textfig. 30, A—C).

The development of the ventral interior is not as well known as that of the dorsal, partly because of the material of the ventral valves not being so well preserved, and partly because of the ventral interior lacking diagnostic features. In the larger larvae, the muscle impressions are somewhat stronger than in the adults, in particular they are better limited posteriorly. In smaller specimens, the muscle impressions will as usual fade out gradually. No traces of diagonal septa, like those found in *Ch. oblonga* and *Ch. subquadrata* can be observed in the larvae. The supraapical pedicle foramen is observed in comparatively small specimens (length more than 4—4,5 mm). The pseudodeltidium is found in all specimens longer than 6 mm. At this size, therefore, the pedicle was completely transferred to the ventral valve.

Ecology: Christiania holtedahli lived on clay bottom only. Just a very small amount of silt and a little calcareous matter is found in the sediments where this species is present.

From the ontogeny, it seems probable that the larvae rested on the comparatively very strong pedicle, and later turned over, and rested on the ventral valve. The fact that the dorsal valve is much lighter than the ventral one (according to a rough estimate 8–12% of the total weight of both valves), and that it is mechanically strengthened by the longitudinal branchial septa gives good support for the theory of the animal living in that position.

When the valves are closed, the branchial septa will be almost in contact with the ventral valve. The animals must therefore have had some special arrangement for the soft parts of the branchia in order to close the valves.

The variable size of this species in the different districts are shown in textfig. 29, and it is discussed above (p. 56).

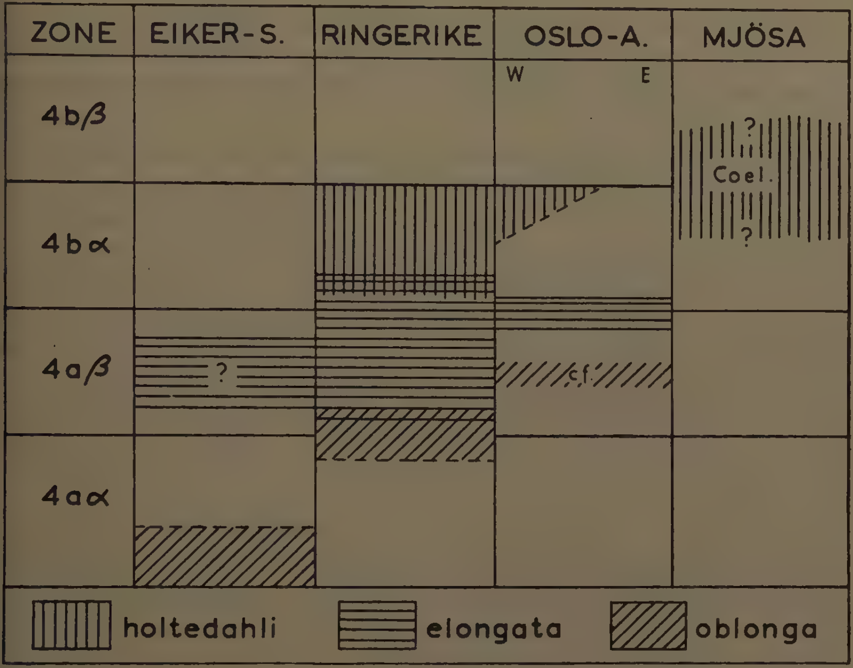

Fig. 31. Diagram illustrating the horizontal and vertical distribution of the *Christiania* species in the Oslo Region.

Remarks: The differences between this species and the other, comparatively well known ones of the genus are mentioned above, or below, under *Ch. elongata* and *Ch. oblonga.*

Distribution. (cf. textfig. 31).

This species is found in zone 4b*α* and possibly the lowest part of 4b*β* in the Ringerike district, in the uppermost part of zone 4b*α* in the Asker district, where it is very common. In the Oslo district, it seems to be absent. It is also found in the Coelosphaeridium zone in Toten, and in the Ringsaker district.

Except in Norway, this species is also common in the Balclatchie group in the Girvan district, Scotland. The records of *Ch. tenuicincta* from Tyrone, N. Ireland, (REED 1953) and N. Wales refer probably to another, younger Ashgillian species which also occur in zone 5a in the Oslo region (cf. HOLTEDAHL 1916, p. 86). GAERTNER (1930) records *Ch. tenuicincta* and *Ch. oblonga* from the Ordovician of the Carnic Alps. Only exteriors are known, and at least some of them might belong to this species.

Christiania cf. *holtedahli* sp. n.

Pl. 6, figs. 8—9.

In the material of *Ch. holtedahli*, there is a ventral interior with some deviating features. Just behind the middle of the valve, at the point of strongest convexity, there is a comparatively large «pocket» in the median line (pl. 6, figs. 8—9). The opening is elliptical in cross section. The cast shows that the pocket is tongue-shaped. The whole specimen is very assymetrical, one side of the valve being much more strongly developed than the other.

This feature is probably due to some damage to the animal in vito. Since, however, a considerable number of assymetrical ventral exteriors have been found from this district, and they are practically all oblique in the same way (the right side is stronger than the left), this may not be an accidental feature. No other interiors of the oblique specimens are observed, and no other specimens showing the ventral interior are oblique. The dorsal valves can not be expected to be assymetrical in the same way, since the hinge-line and outline is symmetrical in all the oblique specimens.

Distribution: All specimens come from zone 4bα (lower part?) at Bratterud, Ringerike district.

Christiania oblonga (PANDER 1830).

Pl. 5, figs. 17—22, pl. 6, fig. 14, textfigs. 5, 27, 26B, and 31.

1830 *Plectambonites oblonga* sp. n. — PANDER, p. 92, pl. 19, fig. 10.
1830 *Plectambonites ovata* sp. n. — PANDER, p. 92, pl. 19, fig. 9.
1845 *Leptæna oblonga* (PANDER)—VERNEUIL, in MURCHISON, KEYSERLING & VERNEUIL, pp. 228—229, pl. 15, fig. 2a—f.

Material: 2 ventral interiors, one dorsal, one complete exterior, and a number of fragmentary casts of exteriors, all from the same layer, probably from the same slab.

Description: Comparatively small species, 3½ mm wide and 3 mm long. Convexity moderate for a *Christiania*. Cardinal angles right, the angle between the areas is 150° in the only specimen in which this feature is preserved. The delthyrium, notothyrium and chilidium is badly preserved, and the pseudodeltidium cannot be observed.

Dorsal interior with strongly developed lateral branchial septa (cf. textfig. 27A), which are fused to the socket plates. The posterior part of the central septa (cb) are only slightly developed, and the loops are not complete. The median septum is very strong, but short. Instead of the anterior part of the central septum, and the transversal septum in *Ch. holtedahli*, there is a pair of wedge-shaped ridges (dp), the pointed ends of which are near the hinge-line, and the blunt, round ends where the median septum begins, at the point of strongest convexity of the valves. No cardinal processes are found in the only dorsal interior present.

The ventral interior has very strong vascular grooves, divided by a pair of intervascular septa. Muscular impressions only slightly developed, and can hardly be distinguished from the posterior end of the vascular grooves. The teeth are badly preserved in the material available, but they appear to be strong. No diagonal septa can be seen, and there is a fine supraapical pedicle foramen (0,3 mm in diam.).

A large number of specimens of *Ch. oblonga* from the type locality, Popovka near Leningrad, have been studied in order to obtain some information on this very interesting strophomenid. The Russian material is probably from zone C1, perhaps also from B3. PANDER applied two specific names to this species, *ovata* for the young ones, which are about as wide as they are long, and with the maximum width at the hinge-line, and *oblonga* for specimens which are considerably longer than they are wide, with the maximum width behind the hinge-line. VERNEUIL (1845) and subsequent authors united the two species, which most probably was correct. All transitions can be found, and sometimes the interior of the *ovata*-type is not fully developed (the branchial loops are not complete). This type is therefore regarded as being the young specimens of the species. There is, however, a possibility of the types occuring in different layers, so that *ovata* might be regarded as a chronological subspecies. The Norwegian material should in that case be referred to *ovata*. The present material is not sufficiently labelled as to zone to give any information on this point. The ventral interior of the Russian specimens are similar to those of the Norwegian ones, except for the vascular grooves being more shallow in most specimens, and the presence of some faint diagonal septa in some of them.

The dorsal interiors vary considerably as to height and thickness of the septa. Their position, however, is stable, and just like the same as in the Norwegian specimen. The cardinal processes also show a considerable variation. In most specimens the cardinal process is triple, with one strong median process, and two smaller ones flanked by the socket plates (pl. 5, fig. 22). This is exactly the same as the cardinal process in the Leptestidae, and some specimens also have a pair of small extra sockets, indicating that the teeth were double. There is no dorsal foramen below the cardinal processes, the pedicle foramen is supraapical in the ventral valve. Behind the cardinal processes, there is a small depression in the valve just where the dorsal foramen is seen in the Sowerbyellinids. Even in thin sections, there is no trace of such foramen. In some specimens (about 25 %) the median cardinal process was reduced, and replaced by a bilobed mass, fused to the socket plates (pl. 5, fig. 20). It is impossible to determine whether these two elements of the cardinal processes are the two smaller, lateral cardinal processes of the first mentioned type (such as in *Oepikina*), or if they are protuberances from the socket plates (such as in the ontogeny of *Ch. holtedahli*). In many specimens the socket plates have some denticles near the notothyrium, and the cardinal processes might be the distalmost of them. In other specimens, an intermediate structure can be found, where the cardinal process is a large mass, with irregular longitudinal furrows, so that it appears to be pentafid or tetrafid (pl. 5, figs. 19, 21). The internal structure is undifferentiated. The specimen figured in textfig. 5 belong to this group.

The shell structure appears to be impunctate. This is probably not due to the state of preservation, since all other features are clearly shown.

Remarks: The fact that most specimens of this species have a complex cardinal process, seems to exclude it, not only from the genus *Christiania*, but also from the whole superfamily Strophomenacea. It is however, evident that it is closely related to the other *Christiania*-species, and the taxonomic consequenses of this observation is discussed above (p. 195).

Ch. oblonga differs from the other species of the genus in a number of features, of which the structure of the cardinal processes is the most striking. Nor is the development of the anterior part of the dorsal central branchial septum and the transversal septum as a special ridge found in any other *Christiania*-species.

Distribution: The Norwegian specimens are from zone 4aα_1 or the lowest part of 4aα_2 (zone of *Did. bifidus*, or lowest part of zone of *Did. geminus*). Associated fauna: *Ullerella triplicata* HENNINGSMOEN, *Tallinella trident* HENNINGSMOEN, and *Alwynella* cf. *ildjernensis*. The locality is 12 m above zone 3cγ, at Muggerudkleiva, Sandsvær—Eiker district. Some additional specimens which may belong to this species have been found in 4aα at Gullerud, Norderhov, Ringerike district.

Christiania cf. *oblonga* (PANDER 1830).

Pl. 5, fig. 13.

Only one specimen has been found of this peculiar form. It is a partly exfoliated complete specimen, showing the dorsal interior. It is small, 4,5 mm wide, and 3,5 mm long, the convexity is just the same as in small specimens of *Ch. oblonga*. The ventral interior and the areas are not known. The dorsal interior is not quite the same as that of *Ch. oblonga* as the septum forming the anterior end of the central septum and the transverse septum is of even thickness, thin, and curved so that it resembles the branchial system in the younger Christianias. It seems, however, to be a discrete plate. The other branchial septa are also high and thin, and there is no difficulty in seeing the complete branchial loops, as is the case with the small specimens of *Ch. oblonga* and *Ch. holtedahli*. The cardinal processes are not preserved, and it is impossible to see whether the lateral branchial septa are fused to the socket plates or not.

If there had been a larger material of this form, it would probably have been made into a new species, intermediate between *Ch. oblonga* and the younger species of *Christiania*.

This only specimen was found in the upper part of zone 4aβ, about 10 m below 4bα, on the southern side of Vassholmen outside Snarøya, Oslo district. It is accompanied by an unusually rich fauna for that zone.

Christiania elongata sp. n.

Pl. 5, fig. 12, textfig. 31.

1954 aff. *Christiania oblonga* (PANDER 1830)—SOKOLSKAJA, pp. 74, pl. 4, figs. 17—18.

Type data: The holotype, PMO 66967, is a cast of the interior of both valves from the transitional beds between zones 4a*β* and 4b*α*, at Sentralinstituttet, Blindern, Oslo district.

Material: 3 casts of the interior of the dorsal valve, 2 of the ventral, and 4 complete casts of the exterior. There are also a large number of fragments, and exteriors which probably belong to this species.

Diagnosis: Christiania species with long, narrow valves, greatest width at the hinge-line, complete branchial loops, and transverse branchial septa in all adult specimens.

Description: Specimens of moderate size, an average specimen is 5,5 mm wide and 8,5 mm long. Areas high, the ventral one triangular, the dorsal rectangular. A pedicle foramen is found in the ventral valve. Pseudodeltidium strongly developed. Dorsal interior similar to that of *Ch. holtedahli*, except for that the transversal septum being considerably less developed than the other branchial septa. The lateral branchial septa are also more evenly curved, and have no raised points at the junction with the transverse septa. The cardinal processes are strong, with a deep fissure between them. The ventral interior is similar to that of *Ch. holtedahli*, except for having some fine diagonal septa. The muscle impressions are also more distinct than in adult specimens of *Ch. holtedahli*. The shell structure is unknown, as all the specimens are either preserved as casts, or in metamorphic rocks.

Remarks: The differences between this species and *Ch. holtedahli* are mentioned above. The two are much alike, and further studies may prove that *Ch. elongata* is a chronological subspecies of *holtedahli*. It has a strong resemblance to young specimens of that species, but differs in the smooth curves of the lateral dorsal septa, and in the shape of the valves, both of which are stable features in the material available. *Ch. elongata* resembles *Ch. subquadrata*, in having diagonal septa. In the latter species, however, the corners of the lateral branchial septa (at the junction with the transversal septa) are strongly pointed, the valves more convex, and the areas lower.

Ch. elongata is united with *Ch. oblonga* (PANDER) through a number of intermediate forms, in Norway occuring in zone 4aα_4 and 4aβ. The typical *oblonga* is smaller, shorter, almost quadrangular, and has a different development of the branchial septa. Some of these intermediate forms have more or less developed diagonal ventral septa, resembling *Ch. subquadrata*. Among the latter are the specimens described by SOKOLSKAJA (1954) as *Ch. oblonga* from the Echinosphaerites zone at Zvjanka near Leningrad. At present the Norwegian material of these intermediate forms is too small to allow a more detailed study.

Distribution: This species is found in zone 4aβ, especially in the transitional beds between this zone and 4bα. Except for the typical specimens from the Oslo—Asker and Ringerike districts, there are some specimens from zone 4aβ in the Sandsvær—Eiker district, which might belong to this species.

Superfamily Strophomenacea KING 1846.

Family Strophomenidae KING 1846.

Subfamily Strophemeninae KING 1846.

A large number of generic terms have been applied to the species belonging to this subfamily.

Leptaena DALMAN 1828 has been misinterpreted by various authors. In this paper the type species is redescribed.

Hedstroemina BANCROFT 1929 and *Kjaerina* BANCROFT 1929 were included in *Rafinesquina* HALL & CLARKE 1892 by SALMON (1942), but differ from the typical members of that genus as to interior structure of the ventral valve. In this paper, they are used as subgenera of *Rafinesquina*.

Actinomena ÖPIK 1930 is probably a synonym of *Kjerulfina* BANCROFT 1929. Both genera have a *Leptaena* (or rather *Oslomena*-) like dorsal interior, but reversed geniculation. The difference between the genera is probably due to their living in different environment. *Actinomena*, which is heavily calcified, lived in calcareous-muddy to sapropelitic sediments. *Kjerulfina* is only slightly calcified, and lived in sand-silt -clay environment with no surplus of lime.

Dactylogonia ULRICH & COOPER 1942 and *Oepikinella* WILSON 1944 are probably synonyms of *Oepikina* SALMON 1942. *Dactylogonia* is said to have only three septa in the dorsal interior, and *Oepikinella* has four, while *Oepikina* has five. In all other repects the genera appear to be identical. The author has studied a large material of the *Oepikina dorsata*-group, and at least here, the relative strength of the septa varies considerably, especially as regards the median septum.

Besides the typical *Oepikina*-species, there are some which have diverging instead of subparallel septa, just like *girvanensis*, and this species is a transition to another group intermediate between *Oepikina*, *Leptaena* and *Rafinesquina*. The dorsal valves have more or less pronounced bilobed muscle impressions, and there is usually a central triangular plate like that in *Leptaena*. These species are included in the new genus *Oslomena*.

Trigrammaria and *Microtrypa* WILSON 1945 differ from *Strophomena* in the development of the dorsal septa, and in the shell structure. The validity of these genera is doubtful, they are probably synonyms of *Strophomena*. Most of the species referred to *Trigrammaria* by WILSON (1945) have a late resupination. About one half of the valve has a «normal» convexity. However, it is doubtful whether this feature is of any taxonomic value.

The classification of the genera within the subfamily Strophomeninae is based on a large number of different features. The convexity and sculpture were used by most older authors, while modern ones have stressed the importance of the shell-structure and the dorsal interior (SALMON, ÖPIK) and the ventral interior. (BANCROFT, HOLTEDAHL). In most cases the author has tried to combine these views, all generic diagnosis are based on internal features, with one exception. As usual, a feature which is stable and of high diagnostic value in one group, might vary considerably in another. It is therefore necessary to have a large material to study the variation in order to evaluate the features to be used in the taxonomy.

Genus *Rafinesquina* HALL & CLARKE 1892.

Subgenus *Rafinesquina* (*Rafinesquina*) HALL & CLARKE 1892.

As defined here, the typical subgenus only includes species with large, flabellate ventral muscle impressions (different from *Kjaerina* and *Oslomena*), and with no, or not fully developed septa in the dorsal valve (different from *Oepikina*). The genus is mainly found in the Upper Ordovician of North America, and only occurs sporadically in the Middle Ordovician of the Oslo region.

Rafinesquina (*Rafinesquina*) sp.

Pl. 8, fig. 8, textfig. 32C.

1916 *Rafinesquina* sp. (cf. *alternata* EM. var *loxorhytis* MEEK)—HOLTEDAHL, p. 22, pl. 1, fig. 12.

Material: Apart from the specimen described and figured by HOLTEDAHL, there is only one fairly complete cast of a ventral interior.

Description: Both specimens have typical *Rafinesquina*-like ventral muscle impressions, and the new specimen is 45 mm wide and 29 mm long. The valves are strongly convex, and the irregular convexity may be due to a distortion of the valves after burial. The geniculation is rounded, and the angle between the disc and the fringe, is about 120°. Otherwise, there is nothing to add HOLTEDAHLS description (l.c.).

Remarks: The present species undoubtedly belongs to *Rafinesquina* (*Rafinesquina*) because of the structure of the muscle impressions, but it is impossible to refer it to any known species owing to the limited material. The specimens are also rather like *Leptaena* (?) *indigena* in size and convexity, and might have been distorted specimens of that species. However, the leptaenoid geniculation, and the long, posterior ends of the muscle impressions are, however, not found in the two specimens mentioned here.

Distribution: In the Coelosphaeridium-zone in the Ringsaker district.

Subgenus *Kjaerina* BANCROFT 1929, and subgenus *Hedstroemina* BANCROFT 1929.

These two subgenera were made to include a number of Rafinesquinids from the Ordovician of Shropshire. The ventral muscle impressions are smaller than in *Rafinesquina* (*Rafinesquina*), and the cardinal processes are long, parallel plates. They also have very thin valves with slightly calcified interior features.

The difference between the genera is that the boundary ridges of the muscle impressions (in the ventral valve) are narrowly diverging (40—70°) in *Kjaerina*, and widely diverging in *Hedstroemina*. (80—120°). *Hedstroemina* also has geniculate valves, while *Kjaerina* has almost flat valves, or slightly geniculated ventral and flat dorsal. In addition, the median ribs are stronger than the others in *Kjaerina*.

Most of the features mentioned above, are of small taxonomic value, at least at the generic level. The sculpture and convexity vary considerably, and the thin valves may be due to ecological features. The angle of the boundary ridges does not seem to be of such an importance that it can be used for separating genera. There are, however, two well defined groups of species which correspond to the subgenera, as defined here. The only exception from the original diagnosis observed by the author, is that the strong median ribs are found in some species with a *Hedstroemina*-like interior, and that they are absent in some *Kjaerina*-species. The author regards these groups as subgenera of *Rafinesquina*.

Salmon (1942) regarded both *Kjaerina* and *Hedstroemina* as synonyms of *Rafinesquina*. Among the species described by that author as a *Rafinesquina*, is *R. robusta* Wilson 1932. If *Hedstroemia* is included in *Rafinesquina* (as a subgenus or as a synonym) this specific name is a homonym of *Hedstroemina robusta* Bancroft 1929. Coincidentally the species seem to be quite like (only the ventral interiors are known).

Rafinesquina (*Kjaerina*) *lepta* sp. n.

Pl. 12, fig. 14, textfig. 32M.

Type data: The holotype; PMO 67133: is the interior of a ventral valve from the lower part of zone 4bδ at Rauskjær, Asker district.

Material: About 15 ventral interiors, and a moderate number of exteriors, and casts of exteriors.

Diagnosis: *Kjaerina* species with rounded geniculation, convex disc, with a slight carina, and scarcely differentiated sculpture. Ventral muscle impressions slightly variable in outline. Dorsal interior unknown.

Description: Small, strongly convex species (average width 16 mm, length 10 mm). Valves rounded geniculated, and with right cardinal angles. Areas low. Sculpture hardly differentiated except for the group of strong median ribs characteristic for the subgenus. The disc is strongly convex.

In most specimens, the ventral interior is of the shape which is typical for the genus (cf. textfig. 34C). Because of the geniculation, the muscle impressions are somewhat longer and broader in old specimens.

The do sal interior is unknown, and the shell structure is finely pseudopunctate.

Remarks: This species differs from other Kjaerinas in the slightly differentiated sculpture, and in the strongly convex disc and geniculation. Species with similar external appearance have been referred to *Hedstroemina*, but he present species have the strong median ribs, and the small angle between the boundary ridges of the ventral muscle impressions which are believed to be typical for *Kjaerina*. It is therefore included in that subgenus.

Distribution: Rafinesquina (*Kjaerina*) *lepta* occurs in the upper part of zone 4bγ, and the lower and middle parts of zone 4bδ in the Asker district. Exteriors probably belonging to this species are found in the Ringerike and Hadeland districts.

Rafinesquina (*Hedstroemina*) *holtedahli* sp. n.

Pl. 8, fig. 14, textfig. 32H.

1916 *Rafinesquina deltoidea* CONRAD (parte)—HOLTEDAHL, pp. 16—18, pl. 1, figs. 4—6, non figs. 2—3.

Type data: The holotype, PMO 66997, is a cast of the interior of a ventral valve from zone 4bα—β at Bratterud, Ringerike district.

Material: 3 ventral interiors, a number of exteriors, and two complete specimens.

Diagnosis: Hedstroemia species with badly defined interior structures, and strongly deflected valves. Umbonal part very convex, and irregularly triangular disc.

Description: A comparatively small species, the holotype is 18 mm wide, 15 mm long and 13 mm high. The valves are subparallel and geniculated. The fringe is long, and the umbonal part of the valves is very convex. The valves are thin, and therefore vary in shape and angle of the geniculation. The disc generally is triangular, but in some specimens irregular, and there are strong undulations parallel to the angle of geniculation. The sculpture consists of fine ribs with 3—4 striae between each. There are also irregular, but strong concentric rugae.

The ventral interior has small teeth, short, strong dental plates, and no trace of the posterior part of the muscle impressions or the pedicle foramen.

The dorsal interior has long, subparallel cardinal processes, and strong socket plates diverging at about 120°. The shell structure is comparatively coarsely pseudopunctate.

Remarks: *R.* (*H.*) *holtedahli* differs from the other species of the subgenus in the shape, which appears to be a constant feature (cf. textfig. 32H.), especially the strong umbonal convexity.

Because of the triangular shape, this species was referred to the incompletely known *Rafinesquina deltoidea* (CONRAD) by HOLTEDAHL (1916). From the descriptions given of the latter species by SALMON (1942) and HALL & CLARKE (1892) the Norwegian specimens evidently are not conspecific with the American ones. They differ in several important features, both in exterior and interior.

Distribution: This species is found in zone 4bα—β in the Ringerike district. The specimens referred to *Rafinesquina deltoidea* (CONR.) by HOLTEDAHL, (1916, pl. 1, figs. 2—3, non figs. 4—6) belong probably to *Rafinesquina* (*Kjaerina*) *lepta* sp. n., and are from zone 4bδ in the Asker district.

Rafinesquina (*Hedstroemina*) *ungula* sp. n.

Pl. 8, figs. 9—11, textfig. 32B.

1916 *Leptaena undata* McCOY (?)—HOLTEDAHL, p. 75, pl. 13, fig. 12.

Type data: The holotype, PMO 7834, is a ventral valve from zone 4bγ at Vestbråten, Ringerike district.

Material: 3 dorsal and 8 ventral interiors, and a large number of complete specimens and valves.

Diagnosis: Abruptly geniculated *Hedstroemina* species with almost flat disc with concentric corrugations, and small, strong ventral muscle impressions with radial striae.

Description: A species of moderate size, average width 30 mm, length 21 mm. The ventral valve is flat, with an abruptly rounded geniculation, which is at right angles to the disc. In some specimens, the disc is slightly convex. The geniculated fringe is generally short, 3—5 mm. The sculpture consists of fine ribs with 4—5 striae between each of them, and strong, usually regular concentric rugae. The areas are low. The dorsal valve is almost completely parallel to the ventral, and in spite of this, the body volume is comparatively large. The valves are very thin.

The ventral interiors have small teeth, dental plates diverging 110°, and ventral muscle impressions with strong boundary ridges, which meet posteriorly in adult specimens and have radial striae. The ventral interior quite resembles that of *Strophomena*.

The dorsal interior has long, blade-like cardinal processes, and strong, thin, stright socket plates.

The shell structure is finely pseudopunctate.

Remarks: This species was referred to as *Leptaena undata* Mc Coy by Holtedahl (l.c.). The specimens figured, (1916, pl. 13, fig. 12) came from the Cyclocrinus Layers at Furuberget, Hamar–Nes district. The whole of the material, with the exception of that specimen, comes from zone 4bγ of the Ringerike district. The possibility of Holtedahls specimen being incorrectly labelled can therefore not be excluded.

R. (*H.*) *ungula* differs from most other species of that subgenus in the abrupt geniculation, and in the strongly developed, but small ventral muscle impressions. Apart from the sculpture, it very much resembles the not very well known *Rafinesquina* (*Hedstroemina* ?) *muensteri* Holtedahl, which occurs in zone 4bα (cf. p. 135).

Distribution: This species is found in zone 4bγ of the Ringerike district, and (?) in the Cyclocrinus Layers in the Hamar–Nes district.

Rafinesquina (*Hedstroemina*) cf. *robusta* Bancroft 1929.

Pl. 8, fig. 5, textfig. 32I.

Material: 4 ventral interiors, and some fragmentary casts of exteriors.

Description: An average specimen is 32 mm wide and 32 mm long. The convexity of the ventral valve is fairly strong and even. The sculpture is rather coarse, and there is not much difference between the ribs and the striae. The cardinal angles are pointed, and the flanks are flatter than the rest of the valves.

The ventral interior has a small, rather indistinct muscle impression, with radial striation. The dental plates are strong and short, and the teeth are not fully developed.

The dorsal interior and the shell structure is unknown.

Remarks: This species evidently belongs to *Rafinesquina* (*Hedstroemina*), and is a transition between this subgenus and the typical one. The species resembles *Hedstroemia robusta* BANCROFT (1929, pl. 2, figs. 6—7) both as to shape, size and sculpture. The Norwegian form differs from the British in the stronger convexity of the latter. It also quite resembles *Rafinesquina robusta* WILSON 1932 (as figured by SALMON 1942, pl. 85 figs. 23—25). As mentioned above, these two rather similar species are homonyms. Apart from the convexity, which is stronger in the Canadian species, and the sculpture, which is coarser in the British, there is no difference between these two species. Since, however, only the ventral valve is known at present, it is possible that the dorsal valves will show more prominent differances. The British species seems to be of about the same age as the Norwegian specimens, while the Canadian species is considerably younger.

Distribution: *R.* (*H.*) cf. *robusta* is found in the Coelosphaeridium zone in the Ringsaker district.

Rafinesquina (*Hedstroemina*) aff. *robusta* BANCROFT 1929.

Pl. 8, figs. 1—4.

Material: 6 dorsal and 5 ventral fragmentary interiors.

Description: The exterior of the species is not very well known. The valves are rather flat, the ventral moderately convex, without geniculation. The sculpture seems to be rather coarse. The specimens are rather large, probably up to 42 mm wide, and 41 mm long.

The ventral interior have widely diverging, very high dental plates, comparatively small teeth, and rather indistinct muscle impressions. The area is moderately high, and the delthyrium broad (120°).

The dorsal interior has long, slightly diverging cardinal processes, strong, low socket plates, and a rather indistinct anchor-shaped platform, which is found in the oldest specimens.

Remarks: This species differs from *R.* (*H.*) *robusta* in the lower convexity, and in the less defined ventral muscle impressions. The dorsal interior is rather like that of *Eostropheodonta williamsi*, but differs in the angle between the dental plates being larger, and in the absence of denticles. Never the less it might indicate that *Eostropheodonta* was derived from species like this one.

Distribution: This species is found in the Coelosphaeridium zone in the eastern part of the Ringsaker district (Brumundal).

Rafinesquina (*Hedstroemina?*) *muensteri* HOLTEDAHL 1916.

1916 *Rafinesquina münsteri* sp. n. — HOLTEDAHL, p. 29, pl. 3, fig. 8.

No new material of this species is available, the holotype is still the only specimen known. It is quite like *R.* (*H.*) *ungula* sp. n. in all features known, except for the concentric rugae being broken by the ribs in *muensteri*, and not in *ungula*. A large number of specimens of the latter species have been studied, but none of them show the type of sculpture found in *muensteri*.

The holotype of *R.* (*H.*) *muensteri* was found in the transitional beds between zone 4bα and 4bβ in the Ringerike district.

«*Rafinesquina*» *ringerikensis* HOLTEDAHL 1916.

1916 *Rafinesquina* (?) *ringerikensis* sp. n. — HOLTEDAHL, p. 30, pl. 3, fig. 7.

Of this species, only the holotype, the specimen figured by HOLTEDAHL, is available. There is nothing to add to his description, the interiors are still unknown. The sculpture is very characteristic, resembling that of *Ptychoglyptus*. The concentric rugae, however, are not broken by the ribs, and the shell structure seems to be different, with ordinary large, pseudopuncta, instead of the small, primitive ones found in *Ptychoglyptus*. The species might therefore belong to the Strophomenidae, but can hardly belong to *Rafinesquina*. Before the interiors have been studied, it is impossible to place this species in the correct genus.

It occurs in the transitional beds between zone 4bα and 4bβ in the Ringerike district.

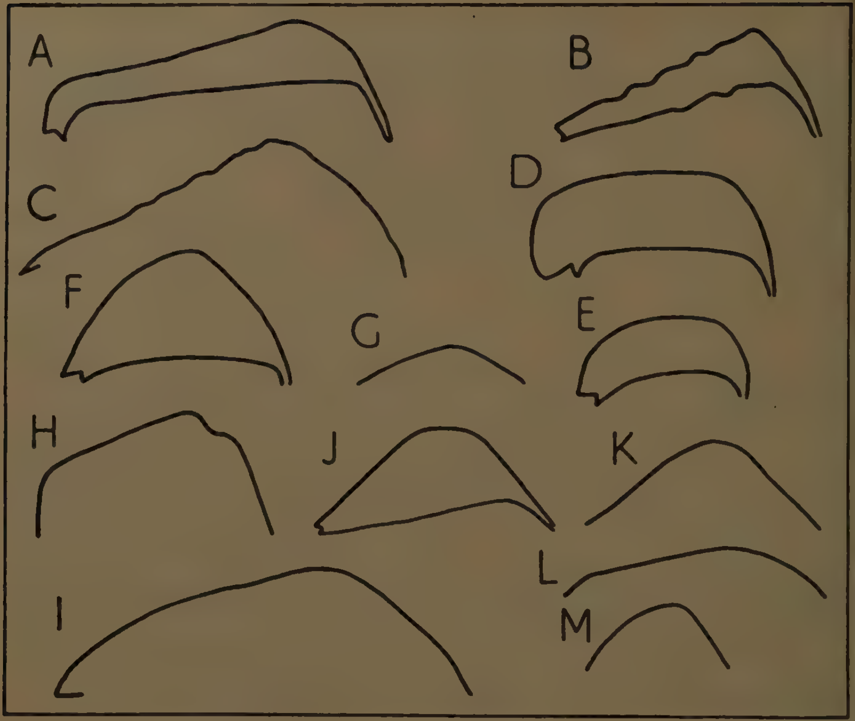

Fig. 32. *Cross-sections of some Strophomenid species.* About 9/10-th natural size. A. *Eostropheodonta williamsi* sp. n. from the Cyclocrinus Shale of the Hamar—Nes district. B. *Rafinesquina* (*Hedstroemina*) *ungula* sp. n. from zone 4bα-β at Bratterud, Ringerike district. C. *Rafinesquina* (*Rafinesquina*) sp. from the Coelosphaeridium Beds in the Ringsaker district. D, E. *Oslomena osloensis* sp. n. D is a large specimen from the Toten district, E, is a typical specimen from zone 4bα at Arnestad, Asker district. F. *Oepikina dorsata media* (ÖPIK 1930) from the Bryozoan Beds in the Langesund—Gjerpen district. G, J. *Mjoesina mjoesensis* (HOLTEDAHL 1916) G. Ventral valve from the Cyclocrinus Beds in the Hamar—Nes district. J. A complete specimen from the Mjøsa Limestone in the Hamar—Nes district. H. *Rafinesquina* (*Hedstroemina*) *holtedahli* sp. n. from zone 4bα-β at Bratterud, Ringerike district. I. *Rafinesquina* (*Hedstroemina*) cf. *robusta* BANCROFT 1929, from the Coelosphaeridium zone (boulder) at Bruflat, Ringsaker district. K. *Mjoesina* cf. *mjoesensis* (HOLTEDAHL 1916) from the Coelosphaeridium Beds of the Ringsaker district. L. *Mjoesina* (?) *gregaria* sp. n. from the Coelosphaeridium (?) Beds of the Toten district. M. *Rafinesquina* (*Kjaerina*) *lepta* sp. n. from zone 4bγ at Hvalstad, Asker district.

Mjoesina gen. nov.

Diagnosis: Strophomenid genus with convex ventral valve, flat, dorsally geniculated dorsal valve, and ventral muscle impressions limited by straight converging septa. Dorsal interior unknown.

Remarks: This genus differs from most others in the development of the ventral muscle impressions. *Kjerulfina*, which has similar, but parallel boundar ridges (or septa), has reversed orientation of the valves. The convexity and shape of the valves is similar to that of *Oslomena*. At present only the type species, *M. gregaria* sp. n. and *M.* cf. *mjoesensis* are included in the new genus.

Type species: Rafinesquina mjoesensis HOLTEDAHL 1916, pp. 19—20, pl. 2, figs. 1—3.

Mjoesina mjoesensis (HOLTEDAHL 1916).

Pl. 8, fig. 6, textfig. 32G, J.

1916 *Rafinesquina mjøsensis* sp. n. — HOLTEDAHL ppp. 19—20, pl. 2, figs. 1—3.
1916 *Rafinesquina* cf. *mjøsensis* sp. n. — HOLTEDAHL, p. 20.
1916 *Rafinesquina parva* sp. n. — HOLTEDAHL, pp. 22—23, pl. 1, fig. 7.

Type data: The lectotype, chosen here, is PMO 38448 a complete specimen from the upper part of the Mjøsa Limestone at Helgøya, Hamar—Nes district. (Figured by HOLTEDAHL 1916, pl. 2, fig. 2).

Material: A large number of specimens, most of them preserved in limestone. Only two ventral and no dorsal interiors.

Description: An average specimen is 17 mm wide and 14 mm long. Ventral valve strongly convex without geniculation. Sculpture consisting of coarse ribs, slightly differentiated. The areas are low, and the delthyrium is very small. The evenly rounded ventral valve, and the rounded geniculation of the dorsal are characteristic features.

The ventral interior has muscle impressions limited by straight lines, the posterior ones being slightly converging, and rather long. (in old, well calcified specimens the straightness and angularity of these lines somewhat obscured by deposition of calcareous tissue at their bases, so that they appear to be rounded, at least in casts, cf. pl. 8, fig. 6). The teeth are strong, triangular. There is a pedicle foramen in all specimens.

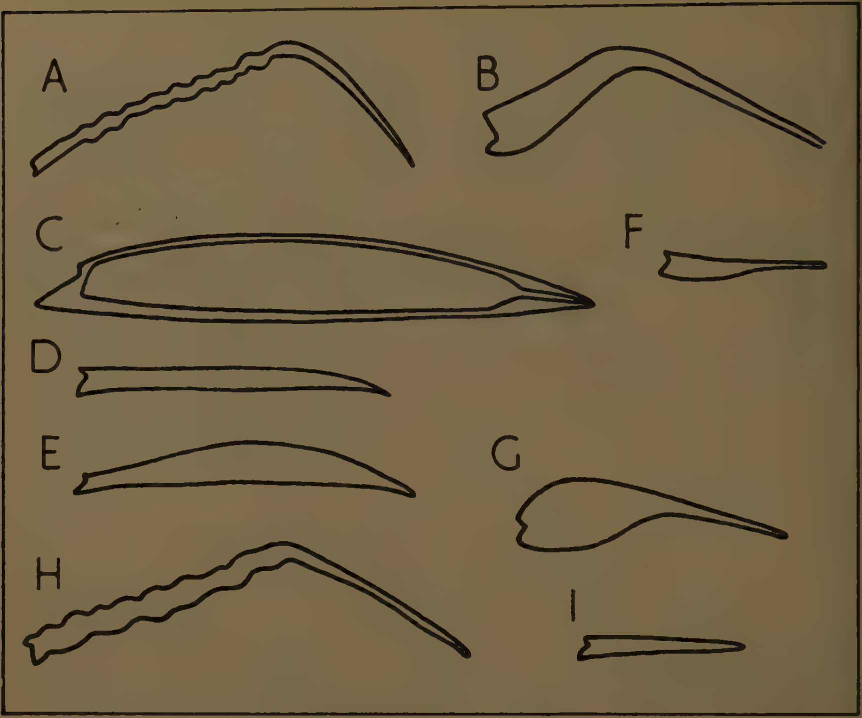

Fig. 33. *Cross-sections of some Strophomenid species.* Magnification about 9/10th. A. *Kjerulfina broeggeri* (HOLTEDAHL 1916), from zone 4bα-β at Bratterud, Ringerike district. B. *Strophomena* (*Gunnarella*) *delta* sp. n., from zone 4bδ, at Gåsøya, Oslo—Asker district. C. *Strophomena steinari* sp. n. from the Coelosphaeridium beds in the Ringsaker district. D. *Strophomena norvegica* sp. n. from zone 4bα at Bratterud, Ringerike district. E. *Strophomena hirsuta* sp. n. from the Coelosphaeridium Beds in the Ringsaker district. F. *Strophomena* (*Gunnarella*) *alpha* sp. n. from zone 4bα at Billingstad, Asker district. G. *Strophomena kjerulfi* HOLTEDAHL 1916, from the Mjøsa Limestone at Helgøya, Hamar—Nes district. H. *Kjerulfina limbata* sp. n. from zone 4bγ at Vestbråten, Ringerike district. I. *Kjerulfina lata* sp. n. from zone 4bα at Nakholmen, Oslo district.

The dorsal interior is unknown. The shell structure is finely pseudopunctate.

Remarks: The closest relative seems to be *M.* cf. *mjoesensis*, which is older and has longer, narrower muscle impressions, and differentiated sculpture. *M. gregaria* sp. n. has smaller muscle impressions, coarser sculpture, lower convexity of the valves, and is larger.

Rafinesquina parva HOLTEDAHL, is included in this species, as young valves of *mjoesensis* cannot be distinguished from the type of *parva*. *Parva* was recorded from older layers than *mjoesensesis*, but specimens of *mjoesensis* are found in the same layers as the type of *parva*.

The specimens mentioned by HOLTEDAHL (1916, p. 20) as «extremely nearly related» to *mjoesensis*, from the Hadeland district, certainly belong to this species. The horizon in which they are found is now referred to as Cyclocrinus-beds.

Distribution: The types of this species are from the upper part of the Mjøsa Limestone, but it occurs in lower horizons too, in the Cyclocrinus beds at Furuberget, Hamar—Nes district, and in the same horizon in the Hadeland district.

Mjoesina cf. *mjoesensis* (HOLTEDAHL 1916).

Pl. 6, fig. 13, pl. 8, fig. 7, textfig. 32K.

(non *Rafinesquina* cf. *mjoesensis* sp. n. — HOLTEDAHL, p. 20).

Material: 3 ventral interiors, and a number of casts of the exterior.

Description: This species differs from *M. mjoesensis* in having much longer and higher plates in the ventral muscle impressions, and the sculpture being clearly differentiated, with 3—4 striae between each rib. The specimens are also slightly larger, and the ventral valve is not so evenly convex. Because of the limited material it is impossible to study the variation in this species. It appears to be considerably more variable as to shape and size than *mjoesensis*.

Distribution: In the Coelospharidium zone in the Ringsaker district. It is remarkable that this species which appear to be more highly developed than *mjoesensis* occurs in older layers.

Mjoesina gregaria sp. n.

Pl. 8, figs. 12—13, Textfig. 32L.

Type data: The holotype, PMO 66996, is the cast of a ventral interior from the Coelosphaeridium zone at Sund, Einavatn, Toten district.

Material: 4 ventral interiors and a number of more or less fragmentary casts of exteriors.

Description: A rather large species, the holotype is 29 mm wide and 21 mm long. Ventral valve moderately convex, dorsal valve almost flat. Ventral area high dorsal, low. Sculpture consisting of coarse, slightly differentiated ribs. Outline uniformly hemicircular, in some specimens, the greatest width is just in front of the hinge-line.

The ventral interior has strongly developed muscle impressions of moderate size. They are deep, and are of the usual *Mjoesina*-shape. The adductors are small, and placed in the middle of the diductors. The vascular system consists of two large ovaria, limited by broad vascula starting at the adductor muscle impressions. The marginal vascular branches are short, and the ovaria, which take up most of the inner surface of the valves, are slightly depressed with an irregularly wrinckled surface.

The teeth are strong, triangular. In gerontic specimens, as for instance the holotype, the anterior surface is vertically striated, resembling the denticulations in the Stropheodontids (cf. pl. 12, figs. 7—8).

The dorsal interior is unknown.

Remarks: This species is referred to *Mjoesina* because of the ventral muscle impressions, but differs from the type species in the low convexity, the size and the coarse sculpture. The small, regularly limited muscle impressions distinguish the species from *Rafinesquina*.

Distribution: In the Coelosphaeridium zone in the Toten district. Fragmentary exteriors with the same sculpture are found in the Hamar—Nes district.

Genus *Strophomena* BLAINVILLE

As defined here (cf. textfig. 34, F, G), this genus both includes species with a comparatively coarse undifferentiated sculpture, and those with fine, well differentiated sculpture. The latter species might perhaps be included in *Longvillia* BANCROFT 1933 (cf. BANCROFT (M S 1949). However, the type species of *Longvillia*, *L. grandis* (SALTER) is not well known, and judging from the figures and specimens seen by the author, the sculpture is not particularly fine or well differentiated.

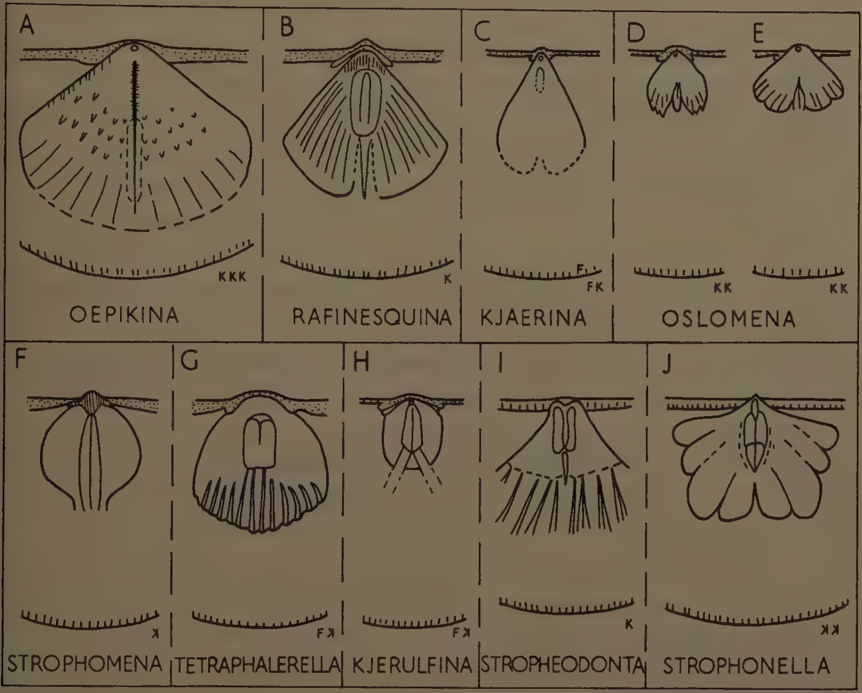

Fig. 34. *The variation of the ventral muscle impressions in the Strophomenidae and Stropheodontidae.* The sources of the figures are: A. *Oepikina dorsata media*, from the Langesund district, cf. pl. 12, fig. 10. B. From Hall & Clarke 1892, pl. 20, fig. 28 (*R. alternata*). C. *Kjaerina geniculata* Upper Longvillian, Road section near Onny River, Shropshire, England. A exceptionally well calcified specimen. D—E. Two specimens of *Oslomena osloensis* from the same population (zone 4bα, Arnestad, Asker district). F. *Strophomena neglecta* (James) Richmond (Waynesville), Blanchester, Ohio, U.S.A. G. *Tetraphalerella planodorsata.* From Wang 1949, pl. 9, fig. D1. H. *Kjerulfina orta* (Öpik) zone C2β, Kukruse, Esthonia. I. From Williams 1953a, pl. 7, fig. 11. (*Stropheodonta* ss. sp.) . J. *Strophonella* cf. *euglypha* from the Mulde Marl, (Upper Wenlock), at Tegelbruket, Frøjel, Gotland. RM. Br. 35731.

The specimens are all reduced to the same size (the curved line below each figure indicate the relative position of the margin of the valve). The letters K, KK and KKK indicate the convexity of the valves, K = slight. KKK = very strong. FK indicate that the valves are generally flat, and geniculated. An inverted K indicate that the convexity is inverse (like that of *Strophomena*).

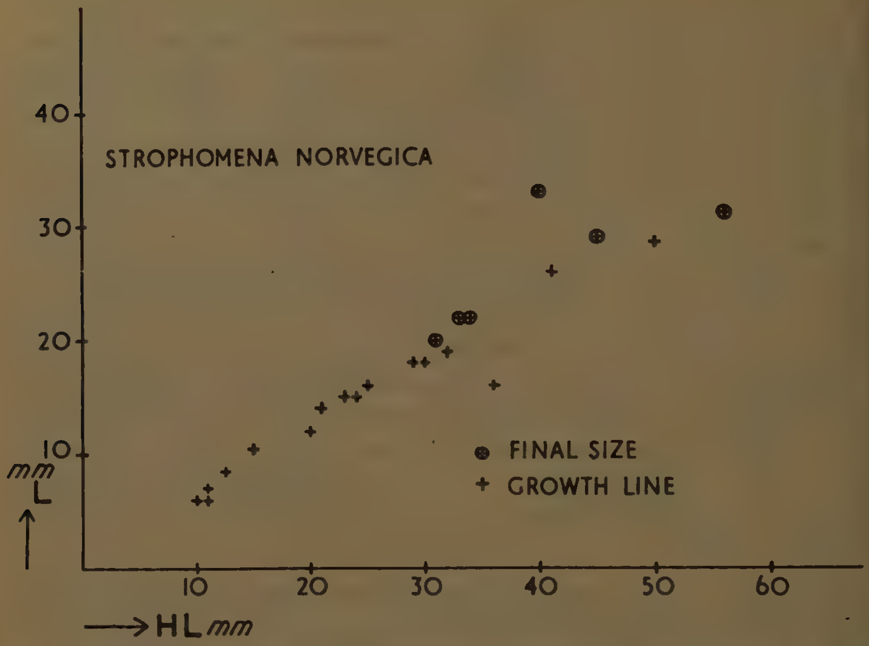

Fig. 35. Diagram showing the correlation between the final outline and the growth-lines in some specimens of *Strophomena norvegica* from the same layer in zone 4bα at Bratterud, Ringerike district.

Only species with distinct resupination, or reversed convexity of the valves are included in *Strophomena*. Species with normal convexity, and reversed geniculation in most cases belong to *Kjerulfina*.

In *Strophomena*, the socket plates are curved outwards and often pointed ventral-wards. In *Kjerulfina* the socket plates are straight, or only slightly curved, whereas they are always straight in *Rafinesquina*.

Strophomena norvegica sp. n.

Pl. 11, figs. 1—3, textfig. 33D, 35.

1916 *Strophomena asmussi* (VERN.) parte HOLTEDAHL, pp. 51—52, pl. 8, figs. 1—6, non figs. 7—8 and pl. 9, fig. 2.

1954 cf. *Strophomena asmussi* (VERNEUIL 1845)—SOKOLSKAJA, pp. 83—85, pl. 5, figs. 1—2, non figs. 3—4.

Type data: The holotype, PMO 7117, is the cast of a dorsal interior from zone 4bα at Røysetangen, Ringerike district.

Material: 5 casts of the dorsal interior, and 7 of the ventral, and a large number of complete specimens and valves in rock.

Diagnosis: Slightly convex, thin-shelled *Strophomena* species, with very long, forked cardinal processes, curved socket plates parallel to the hinge-line, badly defined muscle impressions, ventral diductors flabellate, pseudodeltidium wedge-shaped, and with well differentiated sculpture.

Description: Medium sized, almost flat, thin-shelled species. The size of the well preserved specimens from a population from the type locally is shown in textfig. 35. Surface sculpture consisting of intercalating ribs, with 6—10 striae between each. Every other rib is smaller than the others. Very fine concentric growth-lines occur regularly, about 6 pr. mm at the margin. Near the apex, both the striae, ribs and growth-lines are much finer, without much decrease in number. Coarse growth-lines occur occasionally. Nearly every valve show some irregularites in the sculpture due to fractures in the thin shells during the growth. These healed fractures are found in all parts of the valves, and are often surprisingly numerous.

The areas are high, and there is a supraapical foramen in the ventral valve. The pseudodeltidium is strongly protruding, and rounded wedgeshaped, in some specimens with a median keel. The growth-lines of the area are continuous with those of the pseudodeltidium.

The internal surface is sculptured in the same way as the exterior in young specimens, exept that the growth-lines are missing. In adult specimens, the sculpture fades out in the central parts of the valve, due to the deposition of secondary tissue, which, however, is extremely thin in this species, in spite of it occuring in calcareous rocks. In adult specimens, the fine striae of the sculpture have a wavy appearance near the margin, probably due to the differentiation of the vascular system.

In the dorsal interior, the cardinal processes are very long, thin and forked. They are placed quite close together, with a thin slit between them. The socket plates are strongly curved parallel to the hinge-line, and they are continuous with the socket plates. The muscle impressions are only slightly developed and are divided by a rounded median septum.

Ventral interior with distinct pedicle foramen, and feebly develloped, flabellate muscle impressions. The teeth are long and thin, and they are not fused to the hinge-line, there is generally a thin slit between them.

The shell structure is finely pseudopunctate.

Remarks: The author has not seen any authentical specimens of *Orthis asmusi* VERNEUIL 1845. According to ÖPIK (1930, p. 166) this species is a *Kjerulfina* (= *Actinomena*), and since *Strophomena norvegica* show a number of important differences from the members of that genus, it seems probable that the species described by HOLTEDAHL (1916) is not identical with *asmusi* (That species is also recorded from younger layers than *norvegica*, zone D in Esthonia).

Of the specimens described by SOKOLSKAJA (1954 pl. 5) as *Strophomena asmusi* at least that on fig. 2 belong to *S. norvegica*. Those on figs. 3—4 seem not to belong to the same species, and are also from an other horizon.

Strophomena norvegica belongs to a group of species which is fairly common in the Middle and Upper Ordovician of the Oslo region. They differ from the typical *Strophomena* in the structure of the cardinal processes, which are short and thick, and often strongly curved posteriorly in most other Strophomenas, while they are long, thin and protruding anteriorly in the *norvegica*-group. The ventral muscle impressions are different too, and the typical Strophomenas are generally more convex than *S. norvegica*. The specimens figured by HOLTEDAHL (1916, pl. 8, figs. 7—8) as *S. asmusi* from zone 5a, probably belong to a closely related species, which mainly differs from *norvegica* in the shape of the socket plates. The group is remarkably stable, no important differences can be detected between the specimens from the different districts and horizons, even if they occur in different sediments.

It does not seem necessary to separate this group of species as a new genus or subgenus, even if it differs from the typical *Strophomena* in certain constant features.

S. hirsuta, which is the only contemporaneous species which might belong to this group of species, is larger, with stronger ribs, and better developed muscle impressions.

Distribution: Strophomena norvegica is found in zone 4bα—β in the Ringerike district, and also in the Cyclocrinus zone in Hadeland. (The specimen figured by HOLTEDAHL 1916, pl. 8, fig. 6, is not from stage 4c, the Cyclocrinus beds correspond to stage 4b). The species is also found in zone 4bβ in the Oslo—Asker district.

Strophomena hirsuta sp. n.

Pl. 11, figs. 9(?)—10, textfig 33E.

Type data: The holotype is PMO 67022, the cast of a ventral interior from the Coelosphaeridium beds at Fangberget, Ringsaker district.

Material: 3 dorsal and 3 ventral interiors, and a number of fragmentary casts of both interiors and exteriors.

Diagnosis: *Strophomena* of the *norvegica*-group, with comparatively coarse sculpture, and thick anteriorly curved cardinal processes.

Description: An adult specimen is about 30 mm wide, and 20 mm long. The dorsal valve is evenly and moderately convex, the ventral is flat, or slightly resupinate. The sculpture is clearly differentiated, but comparatively coarse. The ventral area is high, and the pseudodeltidium well developed.

The ventral interior is similar to that of *S. norvegica*, with radial septa instead of lateral ridges. It has a pedicle foramen. The teeth are small.

The dorsal interior show strong, but badly differentiated muscle impressions, which are radially striated. The cardinal processes are short, thick, curved posteriorly, and with a V-shaped muscle attachment. The socket plates are strong, and curved towards the hinge-line.

The shell structure is unknown.

Remarks: This species both resembles *S. norvegica* (as to convexity, the socket plates, and especially the ventral muscle impressions) and the typical Strophomenas (as to the sculpture and the cardinal processes). It differs from *S. keilhaui* in the convexity, and the shape of the ventral muscle impressions.

S. hirsuta also resembless *S. steinari* in many features, but differs in size (they occur together) and ventral muscle impressions. It is difficult to distinguish between young dorsal valves of *S. steinari* and adults of *S. hirsuta.*

Distribution: In the Coelosphaeridium beds in the Ringsaker district.

Strophomena keilhaui HOLTEDAHL 1916

Textfig. 33G.

1916 *Strophomena keilhaui* sp. n. — HOLTEDAHL, pp. 55—56, pl. 7, fig. 8.
1916 *Strophomena asmusi* (VERN.) parte — HOLTEDAHL, p. 52, pl. 8, figs. 4—5.

Type data: The lectotype is PMO 22051, the exterior of a dorsal valve figured by HOLTEDAHL (1916, pl. 7, fig. 8, the left specimen on the figure), from the top of the Mjøsa Limestone at Helgøya, Hamar—Nes district.

Material: From the type locality, the slab figured by HOLTEDAHL is the only material available. It includes 4 dorsal and 3 ventral exteriors, a number of fragments on the side shown in the figure, and 3 fragmentary ventral interiors and some casts of exteriors on the reverse side. A number of specimens have been found in the Cyclocrinus beds at Furuberget, Hamar—Nes district, among them two ventral and a fragmentary dorsal interior.

Description: A specimen of average size is 26 mm wide and 18 mm long. The dorsal valves are evenly convex, with the strongest convexity near the middle of the valve. The ventral valves are resupinate, about 25 % of each with normal convexity.

The sculpture is fine for a *Strophomena*, and every other or third rib is stronger than the rest. In the specimens from Furuberget, the sculpture is well differentiated, with 3—5 striae between each rib. Areas and pseudodeltidium have not been found.

The ventral interior shows a typical *Strophomena*-development, first only the dental plates are developed, then come the lateral ridges, which are shaped like brackets (), and in the adult specimens, the lateral ridges continue into closely placed parallel vascular ridges. The teeth are small.

The dorsal interior is found in a fragmentary specimen from Furuberget. It has a low median septum and almost straight socket plates, only the ends of which are curved towards the hinge-line. The angle between the plates is 100°, considerably less than in most other Strophomenas. The cardinal processes are not preserved.

Remarks: This species differs from the other ones in the different convexity of the valves (large body-volume), in the almost straight socket plates, and the differentiated sculpture. *S. keilhaui* is intermediate between *S. norvegica* or *Kjerulfina limbata* and the later, Upper Ordovician and Lower Silurian species of *Strophomena*.

The specimens from Furuberget, which are included in this species, were referred to *S. asmusi* (= *S. norvegica*) by HOLTEDAHL (1916, p. 52), because of the sculpture being the same. The interiors, however, are like those of the types of *S. keilhaui*. The difference in sculpture might be due to different ecology, and is correlated with the body volume (large volume- coarse sculpture).

Distribution: In the Mjøsa Limestone and the Cyclocrinus beds in the Hamar—Nes district. In the Ringsaker district, it is represented by *S. hirsuta*.

Strophomena steinari sp. n.

Pl. 11, figs. 11—12, textfig. 33C.

Type data: The holotype, PMO 67026, is the cast of a ventral interior from the Coelosphaeridium beds near Bratberg, Ringsaker district.

Material: One dorsal interior, 6 ventral ones, and a few fragmentary casts of the exterior.

Diagnosis: Very large *Strophomena* species, with heavy valves, the ventral one almost flat, the dorsal slightly convex. Ventral muscle impressions of the *Tetraphalerella*-type.

Description: A very large species, the holotype is 61 mm wide and 46 mm long. Even larger fragmentary specimens can be found. The dorsal valve is evenly convex, and the ventral is almost flat, in gerontic specimens with a slight marginal dorsalwards deflexion. The sculpture is coarse, and almost undifferentiated. The areas are high, and the delthyrium and notothyrium narrow.

The ventral interior has strong teeth, and muscle impressions bounded by high lateral ridges. In young specimens, the ridges have the usual *Strophomena*-shape, being closely parallel posteriorly. In old specimens, the posterior part is acute, and the adductor impressions seem to be surrounded by the posterior part of the diductors.

The dorsal interior has two strong cardinal processes, which are bifurcate, V-shaped, and curved anteriorly. The muscle impressions are radially striated, small and not well developed. A short, low and broad median septum is found near the hinge-line.

Both valves have long, equal-sized ciliar grooves, and the shell-structure is pseudopunctate, with puncta of variable size.

Remarks: *S. steinari* differs from all other Norwegian Strophomenas in being so large, and in the absence of resupination. The muscle impressions of the ventral valve, point towards referring this species to the genus *Tetraphalerella* WANG 1942. The latter genus seems to include a fairly homogenous group of Strophomenas, but differs only slightly from the typical members. The adductor muscle impressions are reported to be surrounded by the diductors. Just as in many Strophomenid genera, the shape of the posterior part of the ventral muscle impressions are determined by the vascula media. In *Strophomena*, these vascula seem to start from the end of the adductor muscles, and continue unbranched towards the margin. The parallel ridges are therefore boundary ridges between the vascula media and the diductors, and not between the adductors and the diductors. In the species referred to *Tetraphalerella*, the vascula media branch just behind the adductor muscles, and the diductor muscle does in fact not surround the adductors. The posterior part of the muscle impressions are filled with the vascular impressions and the intervascular septa. It is therefore doubtful whether *Tetraphalerella* can be given more than subgeneric rank. The present species shows typical *Strophomena* features up to the very late stages of growth, and is probably intermediate between the younger *Tetraphalerella* species and Strophomenas of the *norvegica* type (cf. *S. hirsuta*). Of the American species of *Tetraphalerella*, *S. steinari* is rather like *planodorsata* (SCHUCHERT & WINCHELL) cf. WANG 1942, pl. 9, fig. D.

Distribution: All the material of this species is from two localities in the Coelosphaeridium beds in the Ringsaker district.

Strophomena sp.

Pl. 9, fig. 11.

Material: 7 exteriors and casts of exteriors.

Description: A small species, the width is about 10 mm, and the length 7 mm. The valves are resupinate, with a strong umbonal convexity in the ventral valve, and a gentle ventralwards deflection of the valves. The sculpture consists of a few ribs which are especially strong in the median sector of the valves, with 6—8 very fine striae between each. Towards the margin, some of the striae are coarser, and more like the ribs in strength. There are a large number of fine concentric rugae, which are strongest in the lateral parts of the valves.

Remarks: This species can not be referred to any described species of *Strophomena,* although it obviously belongs to this genus. The sculpture shows that it is not a *Gunnarella,* and the roundness of the marginal deflection distinguishes it from *Kjerulfina.* The large umbonal convexity, and the variable sculpture toward the margin might indicate that the present specimens are young or dwarfed individuals of a larger species.

Distribution: In zone 4bδ_2 (of *Tretaspis kiaeri*) at Frognøya, Ringerike district.

Subgenus *Gunnarella* subgen. n.

Type species: Strophomena (*Gunnarella*) *delta* sp. n.

Diagnosis: Strophomenas with a sculpture similar to that of *Ptychoglyptus* (concentric wrinckles cut by radial ribs).

Remarks: This subgenus includes a group of species which have the same internal structure as the typical Strophomenas. The external sculpture, however, is like that of *Ptychoglyptus.* In some species, only the central part of the valve has this type of sculpture, while the margin has no concentric wrinkles.

Many Strophomenids have concentric rugae. In most cases they are of no taxonomic value, being an ecological feature found in a large number of unrelated thin-shelled species. In some cases, rugated specimens are found in species which generally do not have rugae, and vice versa. The type of wrinkles found in *Gunnarella,* however, is of a different kind, and are believed to be of some taxonomic importance. Because of the comparatively limited material, it is impossible to decide whether the subgenus is monophyletic or if that type of sculpture appeared several times independently in *Strophomena.*

Besides the type species, the following ones are included in *Gunnarella: S.* (*G.*) *alpha* sp. n., *S.* (*G.*) *beta* sp. n., *S.* (*G.*) cf. *rigida* (Barrande 1879, em. Holtedahl 1916). *S.* (*G.*) *frognoeenesis* Holtedahl 1916, and probably several others.

The *Strophomena antiquata*-group in the Silurian might be related to *Gunnarella* having the same sculpture. The genus *Drummockina* Bancroft–Lamont (MS) 1949 is reported to have denticulated hinge-line (dental plates ?). Such denticulations are not observed in *Gunnarella*, and this feature is the only important difference between the two genera.

Strophomena (*Gunnarella*) *delta* sp. n.

Pl. 12, fig. 11, Textfig. 33B.

1916 *Strophomena rigida* BARRANDE 1879, parte. — HOLTEDAHL, pp. 56—58.
1916 *Strophomena* sp. — HOLTEDAHL, pl. 9, fig. 9. (cf. expl. to pl. 9).

Type data: The holotype is PMO 67145, a dorsal valve from zone 4*bδ* (6 m below 4c*α*)) from the SW-side of Borøya, Bærum, Oslo—Asker district.

Material: A large number (> 50) of valves in rock, and 12 complete free specimens. The species often occur in masses.

Description: A specimen of average size is 28 mm wide and 17 mm long. The geniculation is generally rounded, and towards the ventral valve. In most specimens the disc is triangular. The shape of the disc, and the roundness of the angle of the geniculation are very variable in this species. Owing to the large populations, it is obvious that only one species occurs. Typical features of all specimens are, however, the comparatively strong convexity (due to the rounded geniculation) and the more or less triangular shape of the specimens. The typical *Gunnarella*-sculpture is found on the disc only. It disappears towards the geniculation and the marginal parts of the valves have only the ordinary sculpture, radial ribs with 4—5 striae between each.

The ventral area is very high. Ventral interior is not well known. Dorsal interior with high, strongly developed cardinal processes, curved socket plates, and three septa in the muscle area. The adult specimens are generally strongly calcified, while the majority of the young valves are extremely thin-shelled, in spite of their occuring in a limestone.

Remarks: This species was referred to the collective species *S. rigida* by HOLTEDAHL (1916). The specimens figured as *Strophomena* sp. from stage 4?, Gåsøya, by HOLTEDAHL (1916, pl. 9, fig. 9) also belongs to this species. The horizon is probably 4b*δ*, where this species occurs abundantly at Gåsøya.

S. (*G.*) *delta* differs from the other species of the subgenus by the dorsal interior being more strongly developed, and from *alpha* also in the convexity. It differs from *S.* (*G.*) *frognoeensis* HOLTEDAHL (1916, pl. 10, fig. 5) in having a larger and more distinct disc, and coarser sculpture.

Distribution: In zone 4bδ in the Oslo—Asker district. A number of the specimens figured by HOLTEDAHL (1916, pl. 10, figs. 1—4) from younger layers may also belong to this species.

Strophomena (*Gunnarella*) *beta* sp. n.

Pl. 9, fig. 12.

Type data: The holotype, PMO 55427, is a specimen showing the posterior part of a dorsal interior, and the ventral exterior, from zone 4bβ at Bratterud, Ringerike district.

Material: Two dorsal interiors, and a small number of exteriors.

Diagnosis: *Gunnarella* species with a very low resupination, and a gently rounded geniculation.

Description: Moderately sized, long species, the holotype is 28 mm wide and 24 mm long. The length of the disc is 12,5 mm. The valves are resupinate, but the convexity of the disc is very low, so that it appears to be almost flat. The geniculation is rounded, and the fringe is curved so that only the *Gunnarella*-sculpture of the disc distinguishes it from the fringe. As usual the fringe does not have the concentric sculpture, and the radial ribs are strong, especially the median ones. 3—5 very fine striae are found between each rib in well preserved specimens. The valves are very thin, and the body-volume is small. The outline of the specimens is rounded triangular, in some ones with a marked median keel.

The ventral interior is unknown, and the dorsal one is not very well preserved either. None of the specimens have the cardinal processes or socket plates. The dorsal muscle impressions are strong, circular, with an irregular boundary ridge, and three intervascular (?) septa in front of it.

Remarks: S. (*G.*) *beta* differs from S. (*G.*) *delta* in the disc being flatter, in the small body-volume, and in the presence of a bundle of strong median ribs. S. (*G.*) *alpha* and S. (*G.*) *rigida* are flat, and generally smaller. S. (*G.*) *beta* is probably the preceding form of S. (*G.*) *delta.* Both species are of the same shape, and have a triangular outline. It is possible that the specimens from Hadeland, which are from a slightly higher horizon, represent an intermediate form between *beta* and *delta*. They are generally better calcified than the specimens from the type locality, a fact which also might be due to differences in the ecology.

Distribution: In zone 4bβ in the Ringerike district, and perhaps also in the Oslo—Asker district (only fragmentary exteriors), and in the Cyclocrinus Shale, just below the Sphaeronid Limestone in the northern part of the Hadeland district.

Strophomena (*Gunnarella*) *alpha* sp. n.

Pl. 11, figs. 5—6, textfig. 33F.

1916 *Strophomena rigida* BARRANDE 1879, parte — HOLTEDAHL, pp. 56—58.

Type data: The holotype, PMO 67021, is a cast of a dorsal interior from the upper part of zone 4bα, west of Billingstad, Asker district.

Material: 6 casts of the exterior and interior of valves from the type locality, and a large number of more or less fragmentary valves and casts of valves from other localities.

Diagnosis: A small *Gunnarella* species, flat, without geniculation, with closely placed, small cardinal processes and deep, small ventral muscle impressions. Characteristic sculpture all over the surface of the valves.

Description: A small, flat species. A specimen of average size is 14 mm wide and 9 mm long. Some large specimens from Arnestadtangen in Asker may belong to this species in spite of being much larger (length: 40 mm, width: 24 mm). See also below, distribution.

Ventral interior with high umbo, and consequently deep, but small ventral muscle impressions. A slightly convex pseudodeltidium covers approximately half of the delthyrium in adult specimens. Dorsal interior only slightly developed, cardinal processes thin, high, and placed close together. Dorsal muscle impressions probably circular, septa only slightly developed. No deposition of secondary tissue on the inner surface of the valves, so that the external sculpture is visible also on the inside of the valves. Ventral area high, triangular, the dorsal one low, rectangular.

Shell structure unknown, probably finely pseudopunctate.

Remarks: This species is the oldest of the subgenus, and it is remarkable in being so small, in not having geniculation and the shell being thin and the interior consequently only being slightly calcified.

Distribution: In zone 4bα, only in the upper and middle part of it, in the Oslo—Asker district. Exteriors of specimens probably belonging to this species are found in the Echinosphaerites zone in the Langesund—Gjerpen district. In the Hadeland district (northern facies, N. of Tønnerudodden) the specimens are considerably larger than the holotype (32 mm wide and 17 mm long). The specimens come from the Cyclocrinus Shale which probably corresponds to zone 4bβ—γ in the Oslo—Asker district.

Strophomena (*Gunnarella*) cf. *rigida* BARRANDE 1879

Pl. 9, fig. 16.

Material: Two exteriors of valves, probably one ventral and one dorsal.

Description: A small species, 10 mm wide and 6,5 mm long. Valves flat, with a small umbonal convexity in the ventral valve. The sculpture is coarse, and of the *Gunnarella*-type. Both the radial ribs and the concentric wrinkles are strong. The interiors and the shell structure are unknown.

Remarks: The present specimens differ from *S.* (*G.*) *delta* in the absence of convexity, and in having stronger sculpture. *S.* (*G.*) *alpha,* which is of about the same size, has finer sculpture and much thinner valves. The specimens are quite like the typical *S.* (*G.*) *rigida* BARRANDE 1879 (pl. 48, figs. VII) except for the size and strength of the sculpture, and they may be an early variety or an ecological type of that species.

Distribution: In zone 4bδ_2 (of *Tretaspis kjaeri*) at Frognøya, Ringerike district.

Genus *Kjerulfina* BANCROFT 1929
(= *Actinomena* ÖPIK 1930)

This genus was made to include species with a ventral interior similar to that of *Leptaena,* and a reversed convexity of the valves.

In most cases (*K. orta*, *K. asmusi* a. o.) the valves are normally convex, but with reversed geniculation. The dorsal muscle impressions are, at least in adult specimens, rather like those of *Leptaena,* and differ from those of *Strophomena.* The geniculation is not an absolutely stable feature in this genus, and in one species at least, *broeggeri* (HOLTEDAHL), normally geniculated specimens are found.

It is difficult to see any difference between young specimens of *Strophomena* and *Kjerulfina*. In *Kjerulfina*, however, the ventral muscle impressions generally have parallel sides, and do not converge towards the anterior end. (Textfig. 34H). *Strophomena* usually has evenly curved sides of the muscle impressions, which converge anteriorly towards the median line. In old specimens, a narrow parallel-sided slit is found at the anterior end (cf. textfig. 34F). This difference in the anterior end of the ventral muscle impressions, is probably due to the size of the median vascula, which are very broad in *Kjerulfina* (pl. 9, fig. 6), and narrow in *Strophomena*. The adductors were placed anteriorly in Strophomena, and posteriorly in *Kjerulfina* (Just as in *Tetraphalerella*). In most Kjerulfinas the socket plates are straight, and the cardinal processes are long and slender, resembling those of *Rafinesquina*.

A feature probably of less importance is that *Strophomena* generally has a coarse, not well differentiated sculpture, while most species of *Kjerulfina* have delicate sculpture, differentiated into ribs and stria. In this feature *Kjerulfina* resembles *Gunnarella*, and still more the *norvegica*-group of *Strophomena*.

Some species referred to *Holtedahlina* (*H. hallie* (FOERSTE 1912), and *H. higginportensis* (FOERSTE 1912)), cf. WANG (1949, p.. 34—35, pl. 7F, fig. 2) and FOERSTE (1912, pl. 2, figs. 1c, 1e, 3a—b, and pl. 10, fig. 4) have the same type of ventral muscle impressions as *Kjerulfina*. The straight, parallel sides of the ventral muscle impressions are best seen in slightly calcified specimens. In strongly calcified specimens (pl. 9, fig. 6) they appear to be curved, but thin sections show that they are parallel in the deeper layers of the valve.

Kjerulfina limbata sp. n. and *K. polycyma* BANCROFT have more *Strophomena*-like ventral muscle impressions than the rest of the genus, but differ from *Strophomena* in having straight socket plates.

Kjerulfina foliovalve sp. n.

Pl. 7, fig. 5, pl. 9, figs. 1—3, 5, 8.

Type data: The holotype, PMO 67004, is the cast of a dorsal interior from the lower part of zone 4bγ in a railway section between Hvalstad and Billingstad, Asker district.

Material: 22 dorsal interiors, 17 ventral ones, few complete specimens, and a large number of casts of valves. There are also some larval valves.

Diagnosis: A large, thinshelled *Kjerulfina* species, of irregular shape and convexity, short muscle impressions, strong cardinal processes and sculpture with many fine, irregular concentric lines.

Description: This species varies considerably as to outline, convexity, sculpture and some internal feature. This is probably due to the very thin valves, which in many specimens seem to be crumbled, as if they consisted of thin paper. The specimens are generally large, up to 52 mm wide and 36 mm long. Most of them are flat, others are more or less convex. In the latter case, the dorsal valve is more convex than the ventral. The real outline is rarely preserved because of the thin shells. Most specimens seem to be rather long, such as the holotype, others are hemicircular. The sculpture consists of ribs with 3—5 stria between each, and a large number of irregular concentric rugae. In some specimens a large number is present, of about the same size, in others they are few and strong. Since the specimens have the same radial sculpture, and since the rugae are possibly due to crumbling and compression of the specimens, they are regarded as belonging to one species.

The ventral interior has small teeth, and the typical *Kjerulfina* muscle impressions, with the side ridges first diverging, then with parallel sides. In some specimens the parallel sides are not developed, and in their place there are fine oblique septa, resembling the ventral interior in *Strophomena norvegica.*

The dorsal interior has strong, parallel cardinal processes, placed on a notothyrial platform, which also has a median septum. The socket plates have an angle of about 120° and are rather high. There is a chilidium. In both valves the layer of secondary tissue is very thin, and the sculpture is visible on the interior.

There are a number of larval valves which are of the same proportions and have the same sculpture as the adults, and are always flat. In some of the valves, there is a carina or sharp fold near the hinge-line, flattening out towards the posterior end of the valve. These valves were first believed to be the ventral ones, the fold was thought to be the impression of the pedicle. Studies of the interiors of the larval valves, however, showed that in the dorsal valve there is a strong groove between the cardinal processes, which are thin and long in these specimens (pl. 7, fig. 5, Pg). The groove is deep, and strongly impressed also on the exterior of the valve. The ventral valves are flat, and only the diverging ridges of the muscle impressions are developed. No groove is found, and no carina on the exterior. In the dorsal interior, the groove is relatively stronger in the smallest specimens, and the cardinal processes cannot be distinguished from the elevated edges of the groove in the smallest specimens.

If this groove is taken for the pedicle groove, the ontogeny of *Kjerulfina foliovalve* shows a considerable resemblance to that of *Christiania*. The smallest larvae are also quite similar, except for the sculpture (cf. pl. 5, fig. 7 and pl. 9, fig. 5).

Remarks: K. foliovalve differs from all other members of the genus in the closely placed ribs, the very variable rugae of the external sculpture, the absence of strong median ribs, and in the well developed notothyrial platform in the dorsal interior. *Kjerulfina lata* sp. n. seems to be the species closest related to it, although it is considerably smaller, and has flat valves of stable proportions.

Distribution: In zone 4bγ in the Oslo—Asker district. Specimens from Hadeland and Ringerike are too fragmentary to be referred to this species with absolute certainty.

Kjerulfina limbata sp. n.

Pl. 9, figs. 4, 9—10, textfig. 33H.

Type data: The holotype, PMO 67011, is the cast of a ventral interior from zone 4bγ at Hole, Ringerike district.

Material: About 15 ventral and 4 dorsal interiors, and a large number of exteriors.

Diagnosis: Large *Kjerulfina* species with curved lateral ridges of the ventral muscle impressions in adult specimens, and short, blunt cardinal processes in the dorsal.

Description: A large species. The holotype, which is among the largest preserved, is 42 mm wide and 31 mm long. The disc is slightly convex, or almost flat, and has a number of regular, weak concentric rugae. The radial sculpture consists of ribs with 3—5 striae between each. A slightly asymetrical bundle of median ribs stronger than the others is found. The angle between the disc and the geniculated fringe is 130—150°, and the geniculation itself is rounded. The areas are comparatively low, the ventral is triangular, and the dorsal thinnest near the notothyrium in adult specimens.

The ventral interior shows the muscle impressions, which are *Strophomena*-like in the adult specimens, and has more parallel sides in the younger ones (cf. Pl. 9, figs. 4 and 10). The teeth are strong and triangular, and there is a thin pedicle foramen. The adductor muscle impressions can rarely be seen and when they are present, they are placed more posteriorly than in most other species of *Kjerulfina*.

The dorsal interior is rather like that of *Strophomena*. The cardinal processes are blunt, rounded in cross-section, and the socket plates are slightly curved outwards. The dorsal adductor impressions are almost invisible. There is a chilidium with a fold corresponding to the slit between the cardinal processes.

The shell structure is coarsely pseudopunctate.

Remarks: As mentioned above, this species is very much like *Strophomena*. The main difference are the geniculation (instead of resupination) and the parallel lateral ridges of the ventral muscle impressions in the young specimens (in *Strophomena* they are curved even in very young specimens). The development may therefore be homeomorphic with that of *Strophomena* rather than indicating that *Strophomena* has developed from *Kjerulfina*. However, the trend of development towards *Strophomena*-like forms is evident both in the Scandinavian and British Middle Ordovician (*K. broeggeri* — *K. limbata* in Norway, *K. trigonalis* — *K. polycyma* in Shropshire).

K. limbata differs from the contemporaneous *K. foliovalve* in being of a more regular shape, in the ventral interior being so distinct, and in having a median bundle of stronger ribs. *K. polycyma* BANCROFT 1929 is still more closely related to it, and differs only in size and in having *Strophomena*-like ventral muscle impressions even in young specimens.

Distribution: In zone 4bγ in the Ringerike district. Some specimens which have a similar exterior can also be found in the Oslo—Asker and Hadeland districts, and they are temporarily referred to this species.

Kjerulfina broeggeri (HOLTEDAHL 1916).

Textfig. 33A.

1916 *Strophomena brøggeri* sp. n. — HOLTEDAHL, pp. 49—50, 100, pl. 7, figs. 3—5.

Type data: The lectotype is L0095, a dorsal valve showing the interior of the cardinal region. The specimen was figured by HOLTEDAHL (1916, pl. 7, fig. 3) and comes from zone 4bα—β at Bratterud, Ringerike district.

Material: One ventral and two dorsal interiors, all artificial casts, and about 55 valves and complete specimens.

Diagnosis: A large *Kjerulfina* species, with strong concentric rugae, and rounded geniculation with long fringe.

Description: Comparatively large species, the lectotype is 42 mm wide and 30 mm long. Since no material of much importance of exteriors, has been collected since the description by HOLTEDAHL, (1916, p. 49) it is not repeated here.

The only ventral interior known, is from a young specimen, and it only shows the dental plates and a fine pedicle foramen. As usual in young specimens, the teeth are scarcely developed, and the side ridges of the muscle impressions are not developed at all. In another specimen, which was dissolved in acid, they appear to be straight, and comparatively short.

The dorsal interior has long, thin cardinal processes, diverging at about 45°. The socket plates are short, inclined inwards, and diverging at 90°. The adductor impressions are well defined in the lectotype, and are rather small, circular, and placed close together. There is a low chilidium. The shell structure is pseudopunctate, with comparatively large puncta, probably of the same size all over the valves.

Remarks: K. broeggeri differs from the Baltic species in the strong sculpture and in the long fringe. The valves are also much thinner in *K. broeggeri*. *K. polycyma* and *K. limbata* have a different shape and dorsal interior, and the ventral muscle impressions are probably not the same either. *K. trigonalis*, the type species, is rather like *K. broeggeri*, but the latter has coarser sculpture, longer fringe and a more distinct dorsal interior. All these differences may be due to changes in ecology, and further studies may show that they ought to be united in one species, which should be named *broeggeri*.

In the material dealt with in this paper, there are some peculiar specimens with «normal» (dorsalwards) geniculation. The specimen which is best preserved was described by HOLTEDAHL (1916, pp. 50, 100) pl. 7, fig. 4), who also mentioned the systematic importance of this discovery. The specimens (four, or possibly five) are like the others as to size, shape and sculpture, and even if no interiors are known, they undoubtedly belong to *K. broeggeri*. The possibility of them being abnormal specimens of *Rafinesquina* (*Hedstroemina*) *holtedahli* sp. n. has been carefully considered, but they differ from that species in many features, and are so like *K. broeggeri* that it is quite evident that specimens with both dorsalwards and ventralwards geniculation occur in this species. The latter are the most numerous, about 90 % of the specimens, or more. The systematic consequences are discussed above.

Distribution: In zone 4bα—β in the Ringerike district, and probably also in zone 4bβ in the Oslo—Asker district.

Kjerulfina lata sp. n.

Pl. 11, figs. 4, 7, textfig. 33I.

Type data: The holotype, PMO 21967, is the cast of a ventral interior from the Coelosphaeridium beds at Furuberget, in the Hamar—Nes district.

Material: 2 dorsal interiors, 6 ventral ones, and a large number of fragmentary casts and exteriors.

Diagnosis: Small, broad, flat *Kjerulfina* species with coarse, well differentiated sculpture.

Description: A rather broad species, two specimens from the Oslo—Asker district are 19 and 25 mm wide and 8,5 and 14 mm long. Hemicircular to hemielliptical outline, right cardinal angles. Valves very slightly convex, or completely flat. Areas low. Delthyrium partly closed by the thin pseudodeltidium. The pedicle foramen small, but persistent in all specimens, even gerontic ones. Sculpture consisting of irregular, coarse ribs with 3—6 striae between each at the margin of the valves. The ribs often stop when they reach a prominent growth-line, giving a discontinuous ornamentation.

Ventral interior with side ridges of the ventral muscles at first diverging at about 120°, then parallel, short. Teeth high, and thin.

Dorsal valve with very strong, vertical cardinal processes placed closely together. The socket plates are remarkable in not diverging from the cardinal processes, but the hinge-line, just outside the notothyrium. Muscle impressions weak, and indistinct. One larval valve shows a strong pedicle (?) scar, and no differentiated cardinal processes. The socket plates, however, are high and strong. This larval specimen is 13 mm wide and 8,5 mm long. It differs slightly from the other ones in the sculpture being more regular, and may belong to another species.

Remarks: This species is referred to *Kjerulfina* because of the shape of the ventral muscle impressions, and the cardinal processes. The convexity of the valves is very slight, and often irregular, probably because of the thin shells in this species. It has no geniculation, but probably belongs to *Kjerulfina* because of the similiarity to young, not geniculated specimen of *K. foliovalve*. The parallel sides of the ventral muscle impressions is characteristic for the genus, see BANCROFT (1929, pl. 2, fig. 9, 1945, pl. 38, fig. 5) and ÖPIK (1930, pl. 10, figs. 131—132).

Distribution: In the upper part of zone 4bα in the Oslo—Asker district, and in the Coelosphaeridium beds in the Hamar—Nes district.

Kjerulfina (?) sp.

Pl. 11, fig. 8.

Material: Two ventral interiors and a small number of casts of the exterior.

Description: A small species, 10,5 mm wide and 16 mm long. Valves strongly geniculated dorsally, Leptaenoid in shape, with fine concentric rugae in the disc, and indistinct radial ribs (due to the preservation). The ventral interior has very long muscle impressions with parallel sides, just as in *Kjerulfina*. The teeth are strongly developed.

The dorsal interior and the shell structure are unknown.

Remarks: This species belongs to a group with an interior similar to *Kjerulfina*, but with reversed geniculation or convexity. Since at least *K. broeggeri* can have the geniculation in either direction, it seems reasonable to include these species in *Kjerulfina*.

The present species seems to be related to *Mjoesina mjoesensis* as regards convexity, but differs in the shape of the disc, the size and the parallel sides of the ventral muscle impressions, which are converging in *M. mjoesensis.*

Distribution: In the Mastopora zone (?) in the Langesund—Gjerpen district.

Genus *Oslomena* gen. nov.

Diagnosis: Strophomenids with convex ventral valve, flat or slightly concave dorsal valve. If geniculated, dorsally. Ventral muscle impressions small, sometimes bilobed, surrounded by a ridge. Dorsal interior variable from specimens with diverging septa like *Oepikina* to those with strong bilobed muscle impressions like the earliest species of *Leptaena.*

Type species: Oslomena osloensis sp. n.

Oslomena osloensis sp. n.

Pl. 12, figs. 12—13, 15—16, textfigs. 32D—E, 36—37.

1916 *Rafinesquina* cf. *imbrex* (PANDER) parte — HOLTEDAHL, pp. 15—16, pl.1 figs. 10—11, non fig. 8.

1917 *Rafinesquina* (*Playfairea*) *deltoidea* (CONR.) parte — REED, p. 886, pl. 11, figs. 21—30.

Type data: The holotype, PMO 67142, is a cast of the interior of both valves, and the exterior of the dorsal valve, and parts of the ventral one, from the upper part of zone 4bα at Billingstad, Asker district.

Material: 14 interiors of both valves, 11 complete, free specimens, a large nnmb of casts of exteriors or interors, and valves and complete specimens in roek

Diagnosis Oslomena species with regular strong convexity of the ventral valve, and with flat dorsal with a rounded geniculation. Well differentiated sculpture.

Description: Specimens of variable size (cf. textfig. 37). The strongly convex ventral valve is geniculated. There is no disc, or only a very small one in the umbonal part of the valve.

The dorsal valve is always roundly geniculated. The specimens are generally broadest along the hinge- line. Several growth-types are found in the material dealt with in this paper (cf. p. 53). The typical form (from Billingstad, Nakholmen and Bratterud) has a rounded triangular outline, is comparatively large, and has a HL/L ratio of 1,25—1,45. Another type is considerably smaller, with a more rounded outline, and HL/L ratio of 0,91—1,05. It is interesting to note that in all localities from which a large material is collected, only one of these types occur, and both types are never found together in one locality. In other localities, where the material is more limited, other types are found, some being very flat, and some having a stronger convexity than the ordinary ones. In some northern localities, there are also some larger specimens (textfig. 37, B).

It does not seem advisable to discriminate species and subspecies on the growth-types referred to here. Transitional forms occur, and there are no differences as to the internal structures, at least none which can be correlated with the growth-types. The geographical distribution is interesting, too. The first type is found along a 50 km long line, running almost E—W, ranging from rather poor fauna in east to a very rich in west. The other one is more local, found in the Asker district only, about the middle of the line of distribution of the first type. The distance between localities with different growth-types is in some cases less than one km. The distribution of the different growth-types must therefore be attributed to ecological variations which do not reflect themselves in the sediments.

Studies on the growth-lines indicate that, in the dorsal valve, the disc was formed first, with HL/L ratio about 1,4, rounded, with right cardinal angles. When the geniculation took place, the lateral growth decreased rapidly, just as in most geniculated species. The areas therefore have rounded ends instead of being triangular (textfig. 36). The ventral area is high with a delthyrium surrounded by a strong, elevated ridge. The apical angle of the delthyrium is about 95—105°. It is covered by a thick massive pseudodeltidium, with lamellar structure. The growth-lamellae are straight, and very prominent in the central part, bending steeply down towards the notothyrium. This feature is generally not preserved in ordinary specimens. When the shell substance is dissolved in hydrochloric acid, the finer details as well as the bends of the lamella can be seen (pl. 12, fig. 16).

In some well preserved specimens, the relations between the cardinal processes and the pseudodeltidium can be observed. The cardi-

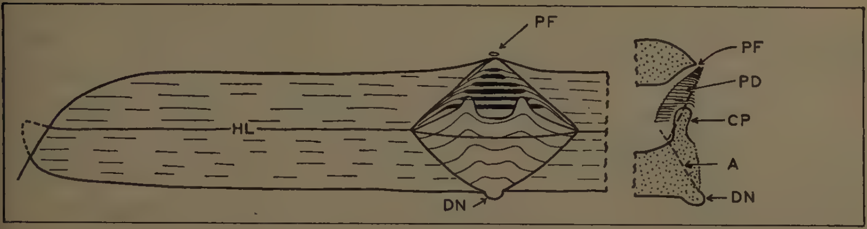

Fig. 36. *Diagramatic figure of the area of Oslomena osloensis sp. n. in frontal and lateral view.* The figure is based on several specimens from two different localities, and show the features of an average, mature specimen. All the specimens are from zone 4bα, in the Asker district.

Abbreviations: A = Projection of the areas into the lateral, central view. Note that the dorsal area overlap the ventral for some distance. CP = Cardinal process. DN = Dorsal node (Pedicle scar?) HL = Hinge-line, the line of contact of the valves, just below the edge of the dorsal area. PD = Pseudodeltidium. PF = Pedicle foramen.

nal processes in these gerontic specimens are completely surrounded by the pseudodeltidium so that the diductor muscles can not have been attached to the cardinal processes, at least not to their ends. This peculiar feature was observed in two, probably three specimens, the only in which the pseudodeltidium was large anongh. The author is unable to give any satisfactory explanation to this feature. None of the specimens appear to be pathological, and they are definitely not distorted.

In young specimens, the dorsal area is similar to the ventral one, except for being slightly lower. In older specimens, the dorsal area is considerably higher on the sides than in the middle, probably due to differential growth along the hinge-line. The dorsal area is also somewhat longer than the ventral one, due to the ventral valve overlapping the hinge-line (textfig. 36). The notothyrium is parabolic in outline, and completely filled with the chilidium, on which the cardinal processes rest. The growth-lines indicate that the cardinal processes diverged during the growth of the valve. A dorsal node is found below the chilidium. It is very prominent in the young specimens, but as it does not grow, it is less prominent in the adult specimens. In this species, the node is attached to a small shaft, with two small depressions, one on each side. The node is fused to the chilidium. In *Christiania*, a similar node represents the scar of a dorsal foramen.

The sculpture consists of a large number of ribs with 5—8 striae between each. At the apex of the ventral valve there are 3 ribs, while 4—5 are found on the dorsal valve. At the margin, the number of ribs seems to be the same in both valves (about 30). The distance between each rib is from 1 mm to slightly less than 2 mm. The new ribs are formed by intercalation, and a number of them starty contemporaneously at the same strong growth-line.

Dorsal interior: Cardinal processes strong, formed by two slightly diverging plates with subparallel sides and rounded tops. Socket plates diverging at about 120°, ends ancylosed to the base of the cardinal processes. No diaphragm around the disc has been observed. Median septum developed in the central and anterior part of the valve only, resembling the x-plate in the Plectambonitacea. The lateral septa are differently developed. In most specimens the first pair is U-shaped with the open ends converging towards the cardinal processes at about 100°. In some specimens only the posterior branch of the «U» is developed, or it is much stronger than the other one. The second pair of lateral septa converges towards the median septum. In old specimens, the septa are sometimes elevated into strong, vertical nodes. The septa of this species are rounded in cross-section, and differ considerably from the thin, sharp-edged, subparallel ones in *Oepikina*.

Ventral interior: Muscle impressions bounded by a prominent ridge from the rest of the valve. A small number of radial ridges may occur in the muscle impression. The impressions are pointed, or rounded posteriorly (cf. textfig. 34 D—E). The dental plates are strong, diverging at about 100°. Vascular impressions appear as two strong branches from the ends of the muscle impressions. In some specimens traces of large ovarian impressions, covering almost the whole surface of the valves are also found, together with short marginal vascula. A median septum is found in some specimens (pl. 12, fig. 15), generally it is small, and fairly low. The adductor impressions are not clearly distinguished in most specimens. They seem to be placed far posteriorly (textfig. 34 D—E).

Ontogeny: The early development of this species is known from the growthline studies on adult specimens. Only one «larval» valve is found. The larva probably were planconvex, with low triangular areas. The young specimen present is a perfectly flat dorsal valve, which has a remarkably strong dorsal node. The sculpture and internal structure is the same as in the adult specimens. It is 7 mm wide and 4,5 mm long. The adult specimens from this locality are about 10—11 mm wide and 10—12 mm long.

Shell structure: According to SALMON (1942) an important difference between *Oepikina* and *Rafinesquina* is that the pseudopuncta of *Rafinesquina* are large and placed in radial rows, while the small puncta of *Oepikina* are evenly distributed over the surface of the valves. *Oslomena osloensis* has larger pseudopuncta than the marginal ones in *Oepikina dorsata* (from C 2, Kukruse, Esthonia cf. pl. 13, fig. 2), and of more uniform size (cf. p. 11). The size of the pseudopuncta, however, is not a reliable feature when it comes to discriminating between genera, at least not in Norwegian material.

Remarks: In spite of the rather wide variations found in size, shape and dorsal interior, it does not seem necessary to split this species. The presence of one type in each locality (cf. textfig. 37) and a number of common features indicate that all specimens belong to one, variable species, possibly with a number of local races. It seems to be intermediate between *O. celtica* (HARPER 1952) and *O. girvanensis* (REED 1945). *O. osloensis* is smaller than *O. celtica*, and seems to have more striae between the ribs (5—8 against 3—4). In the larger specimens the outline too is different. *O. girvanensis* is smaller, and the small specimens of *O. osloensis* lack the triangular outline. Within the limits of variation, the dorsal interior of *O. osloensis* shows specimens like both *O. girvanensis* and *O. celtica*. It is also probable that some of the specimens figured by REED (1917, pl. 11, figs. 21—30) could be included in *O. osloensis*. The ventral interior of *O. celtica* has bilobed muscle impressions which is not found in *O. osloensis*, and *O. girvanensis* has a strong median septum, which is seldom developed in *O. osloensis*. It differs from *O. baylei* and *O. multicorrugatella* in having more strongly developed internal structures, larger muscle impressions, and in the external sculpture.

The Russian specimens described by SOKOLSKAJA (1954, pp. 43—46, pl. 2, figs. 14—20) as *Rafinesquina* (*Playfairea*) *deltoidea* (CONRAD) may belong to this species. They differ considerably from CONRADS species as defined by SALMON (1942). The subgenus *Playfairea* REED 1917 sensu SOKOLSKAJA 1954 is the same as the new genus *Oslomena*. Since the type of *Playfairea* (*deltoidea* CONRAD) is a

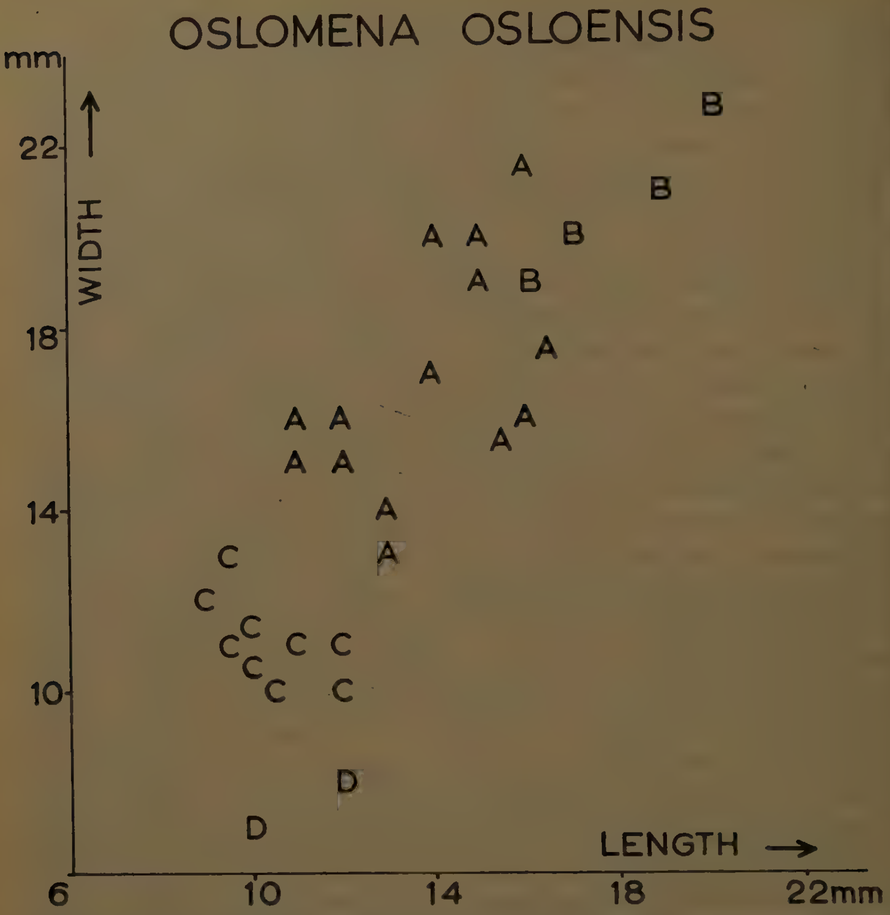

Fig. 37. Diagram showing the variations in size of *Oslomena osloensis* sp. n. from various localities in the Oslo Region. A. indicate typical specimens, populations from Billingstad, Blakstad and Bratterud. B. Indicate the larger specimens from the Toten district. C. indicate the small variety from the populations at Slependen and Gåsøya, Oslo—Asker district. D. are typical specimens of *Oslomena* cf. *girvanensis* (Reed 1945), from zone 4bβ, at Gomnes, Ringerike district. Only complete, undamaged specimens are measured.

typical *Rafinesquina*, the name *Playfairea* can not be used instead of *Oslomena*.

Distribution: In the upper part of zone 4bα and probably (large specimens) in the lowest part of zone 4bβ in the Oslo—Asker district, in zone 4bα—β in the Ringerike district, and in the Coelosphaeridium beds of the Toten district, and possibly also the Hamar—Nes district. In the Langesund—Gjerpen and Ringsaker districts it seems to be replaced by *Oepikina dorsata media*. It is also probably found in the Balclatchie group in the Girvan district, Scotland, in the Chasmops beds in Dalecarlia, Sweden, and in the Baltic region.

Oslomena aff. *girvanensis* (REED 1945).

Textfig. 37D.

cf. 1917 *Rafinesquina* (*Playfairea*) *deltoidea* (CONRAD) — REED, pl. 11, fig. 23, non figs. 21—22, 24—30.
aff. 1945 *Playfairea girvanensis* sp. n. — REED, p. 311.

Material: One complete specimen, exfoliated to show the dorsal interior. A number of single valves from the same layer and locality are also referred to the same species because of similarity in shape.

Description: A small globose species, longer than broad (cf. textfig. 37 D). The dorsal interior very much resembles that of *O. girvanensis* (REED 1917, pl. 11, fig. 23). The septa are somewhat obscured by deposition of secondary calcareous tissus, so that they appear to be confluent, forming a triangular area, like that in the dorsal valve of certain *Leptaena*-species. The present species differs from *O. girvanensis* in being smaller, and in the proportions (*O. girvanensis* is wider than long).

Distribution: The specimens referred to this species are all from zone 4bβ at Gomnes—Rud, Ringerike district.

? *Oslomena celtica* (HARPER 1952).

1916 *Leptaena* sp. (cf. *unicostata* M & W) — HOLTEDAHL, p. 74, pl. 13, fig. 2.
?1952 *Øpikina celtica* sp. n. — HARPER, pp. 103—104, pl. 5, fig. 7, pl. 6, figs. 10—11.

Material: One specimen, a ventral interior figured by HOLTE—DAHL (l.c.). A number of casts of exteriors from the same locality may belong to this species.

Description: The specimen is 21 mm wide along the hinge-line The projection of the length is 13 mm and the length of the disc is 10 mm. The angle of geniculation is 105—110°. The long and narrow ventral muscle impressions are bilobed. It resembles the figures given of *O. celtica*, but is somewhat smaller and broader. The muscle impressions are also similar. In the Norwegian specimen, the lateral lobes, however, are slightly smaller. *Leptaena unicostata* MEEK & WORTHEN, is described by WINCHELL & SCHUCHERT (1892, p. 412, pl. 32, fig. 8). There are also a number of specimens in the material examined by the author. The disc is larger, and the concentric wrinkles are generally observed in the interior of *L. unicostata*, which also has very strong pseudopuncta. The puncta found in ? *O. celtica* are very small.

Distribution: O. celtica is recorded from Grangeeth, County Meath, Eire, in layers probably corresponding to the upper part of zone 4b*α* in the Oslo region. The Norwegian specimens are from Gravestrand, Frierfjord, in the Langesund—Gjerpen district, and come from the upper part of the Echinosphaerites beds.

Oslomena (?) *papillio* sp. n.

Pl. 9, figs. 13—15.

Type data: The holotype, PMO 38184, is the cast of a small dorsal interior from the Coelosphaeridium (?) beds in the Toten district.

Material: One dorsal and one ventral interior, and a number of casts of the exterior.

Diagnosis: Oslomena (?) species with slightly convex ventral valve, flat dorsal, and coarse, undifferentiated sculpture.

Description: A small species with slightly convex ventral valve, and almost flat dorsal. A specimen of average size is 15 mm wide and 12 mm long. The areas are low, and the sculpture is paucicostate, and comparatively coarse. The ventral interior shows strong, posteriorly inclined teeth, and *Rafinesquina*-like, small muscle impressions with a dividing septum in the anterior end.

The dorsal interior is remarkable, with two diverging septa, and a forked median septum. The cardinal processes are comparatively large, elliptical in cross-section, and a chilidium is present. The interior of the valves are smooth, and the shell-structure is unknown.

Remarks: This species can not with certainty be placed in any known genus. It resembles *Holtedahlina* in sculpture, *Rafinesquina* in shape, and *Hedstroemina* in the small muscle impressions. The dorsal interior is similar to that of *Microtrypa* WILSON (1945), and this type of interior is not known from any other species with similar convexity. Further collecting may give more material, which will show if the species should be included in a new genus.

Distribution: In the Coelosphaeridium (?) beds in the Toten district.

Genus *Oepikina* SALMON 1942.

Oepikina dorsata media (ÖPIK 1930).

Pl. 12, figs. 9—10.

1916 *Rafinesquina imbrex* (PANDER) parte — HOLTEDAHL, p. 15—16, pl. 1, fig. 8, non figs. 10—11.

1930 *Rafinesquina dorsata media* subsp. n. — ÖPIK, pp. 189—190, pl. 14, figs. 161—164.

Material: 6 dorsal interiors 5 ventral and a number of exteriors of single valves. All specimens preserved are casts, and all except one come from altered shale.

Description: The Norwegian specimen seem to be slightly larger than the Baltic ones. (cf. ÖPIK 1930, p. 190). The dimensions of the following four dorsal interiors are characteristic (all measurements are in mm).

Length of disc	Hinge line	Greatest width	Angle of genicula-tion
10	11	14	125°
10	14	16	—
9	11	12	110°
13	12	14	—

The exteriors of this species are badly preserved, and the details of the sculpture can seldom be observed. In the specimens with well preserved surface, ribs and striae are found, just as in the Baltic specimens of this species (cf. ÖPIK 1930, pl. 14, fig. 161). The distance between the ribs might be larger in the Norwegian specimens, and the striae generally better defined. The ventral valve is generally strongly convex, with only slightly marked disc. Diductor muscle impressions very large, expanding over most of the inner surface of the valve. A number of strong, radial ridges are found in the muscle impressions. The adductor impressions are small, narrow. They are placed posteriorly

There is a strong median septum between the two pairs of muscle impressions (cf. textfig. 34 A). A thin pedicle foramen is observed in most specimens.

Dorsal valve abruptly geniculated, with subpentagonal, slightly concave disc with a strong boundary ridge. Short, forked cardinal processes. Socket plates fused to the boundary ridges. Development of branchial septa variable. In some cases the median septum is very small (resembling *Dactylogonia*) and in others, the central pair of septa is almost lacking (resembling *Oepikinella*). In some specimens a thin connection ridge is found between the lateral septa on each side, uniting them into what resembles a branchial loop (cf. textfig. 28 A). The latter feature is clearly seen on the Norwegian material only, while the development of the septa is studied on a large material of *Oepikina* species from Esthonia.

Remarks: This species is evidently a member of the *Oepikina dorsata*-group. In the dorsal interior it is in all details like *O. dorsata media* (ÖPIK). The Norwegian specimens appear to be slightly larger than the Baltic ones.

Distribution: In the Langesund and Ringsaker districts. The few specimens from the Ringsaker district are from the Coelosphaeridium beds, and the more numerous ones from the Langesund—Gjerpen district are from the Echinosphaerites — Bryozoan zones along the shores of Frierfjord. They seem to occur in a thin band only, probably in the lower part of the Bryozoan zone. In Esthonia (ÖPIK 1930, p. 190) it is common in zones C_2 and $C_3\alpha$.

Oepikina (? or *Rafinesquina*) sp.

Pl. 12, fig. 11.

Material: One fragmentary cast of a ventral interior.

Description: The specimen is 19 mm wide, and 17 mm long. It is strongly convex, slightly angular in outline and evidently belonging to an adult specimen. The teeth are strong, and the muscle impressions large, narrow anteriorly, badly defined posteriorly, and have strong radial septa. The shell structure and sculpture are unknown.

Remarks: The specimen must be referred to *Oepikina* or *Rafinesquina* (*Rafinesquina*) because of the muscle impressions. The specimen differs both in shape and size from the Norwegian species of *Oepikina*. The ventral muscle impression is also smaller than is usual in that genus. As there is no dorsal interior present, it is impossible to decide if the specimen belongs to *Oepikina* or *Rafinesquina* (*Rafinesquina*).

Distribution: Judging from the other fossils found together with this specimen, the horizon is the uppermost part of 4aβ or the transitional beds between 4aβ and 4bα. The locality is Vesleseter in the Sjåstad district.

Genus *Leptaena* Dalman 1828.

Type species: Leptaena rugosa Dalman 1828 (non Hisinger 1827), selected by King 1846.

Diagnosis: Strophomenids with strong, slightly differentiated sculpture, more or less pronounced concentric wrinkles, and generally a very strong geniculation, in connection with a ridge around the disc. Ventral interior with strong teeth, muscle impressions of variable size and shape, flabellate or with evenly curved or parallel sides. Adductor impressions small, in the middle of the diductors, and often surrounded by them. Dorsal interior with strong cardinal processes, rounded, often perfectly circular muscle impressions, and occasionally with a complex median septum. Shell substance coarsely pseudopunctate.

History of the generic name: Several types of species were included in *Leptaena* by Dalman, and this has led to some confusion. Davidson (1856) and McCoy (1852) based their diagnosis of the genus on *transversalis* (= *Plectodonta*). The selection of *L. rugosa* as the type species by King (1846), however, is definite, and was apparently repeated independantly by Dall (1877, pp. 34, 41) and Hall & Clarke (1892, p. 276). The type species has generally been placed in synonymy with *Conchites rhomboidalis* Wilckens (1769), a badly known species, which has been recorded from the Lower Ordovician into the Carboniferous. It has, however, to be mentioned that this author did not apply binominal nomenclature, his name of the species was *Chonchitas Rhomboidales anomios inaequilateros* (l.c. p. 79). The specific name *rhomboidalis* in connection with *Leptaena* should therefore be attributed to Wahlenberg (1821, p. 65).

POULSEN (1943) redefined this species, and although it is not absolutely certain that the species figured by POULSEN is identical with that of WAHLENBERG, *L. rhomboidalis* is used in this paper as it was defined by POULSEN. On the basis of material from the Silurian of Gotland, this author also redefined *L. depressa* (Sow.), another species which has generally been included in *L. rhomboidalis* sp. coll.

A restudy of the type material of DALMAN (preserved in the Paleozool. avd., Riksmuseet, Stockholm, Sweden), showed that the type of *L. rugosa* were not from the Silurian of Gotland, such as supposed by most authors. They were from the Upper Ordovician Dalmanitina layers in Västergötland, Sweden. As early as in 1908 SCHMIDT suspected this, and in fact it was quite evident from the original description (DALMAN 1828, p. 106 «observatu dignum videatur in schisto superiore montium Vestrogothiae hujus speciei exemplaria numerosa esse obvia, — — —». All other specimens of *Leptaena* in his collection differ in shape, size and proportions from those figured by DALMAN (1828, pl. 1, fig. 1).

Besides SCHMIDT (1908), SOKOLSKAJA (1954, pp. 56—57, pl. 3, figs. 3—9) seem to be the only author who has recognized *L. rugosa* as an Ordovician species. None of the specimens described by the latter author seem, however, to belong to *L. rugosa*. The specimens figured on pl. 3, fig. 3a—b and possibly fig. 7 might be *Hedstroeminas*, because of the prominent bundle of median ribs. The specimen on fig. 6 recall *Kiaeromena juvenilis* (ÖPIK 1930), and that on fig. 8 is quite like *L.* (?) *indigena* sp. n.

L. rugosa is generally referred to HISINGER (1827). *L. rugosa* (HIS.), however, is a nomen nudum, and the species must therefore be referred to DALMAN (1828).

A number of genera have been made for species of the *Leptaena*-group. Most of them (*Leptagonia* McCOY = *Leptaenella* SOKOLSKAJA 1952, and *Pseudoleptaena* MILRADOVICH 1947, sensu SOKOLSKAJA 1952) are probaly only subgenera of *Leptaena* if they can be given such rank.

The author has not seen *Notoleptaena* GILL. It appears to be a good genus, closely related to *Leptaena*.

In this paper a new genus *Kiaeromena*, type species *Leptaena kjerulfi* HOLTEDAHL 1916, is described. It differs from *Leptaena* in the cardinal processes, and in the shape of the valves.

Leptaena rugosa has, like most Ordovician Leptaenas, flabellate ventral muscle impressions, whereas the Silurian species generally have narrow impressions, with gently curved, or parallel sides. It might therefore be advicable to use *Leptagonia* McCoy (= *Leptaenella* Sokolskaja) as a subgeneric term for the Silurian and younger species.

The stratigraphical range of *Leptaena* (*Leptaena*) is, in this case, restricted to the Middle and Upper Ordovician, and possibly the basal Silurian.

Leptaena rugosa Dalman 1828.

Pl. 7, figs. 1—2, 4, textfigs. 38G, 39A.

Type data: The lectotype, here chosen, is specimen nr. Br. 10435 (Riksmuseet, Stockholm), a cast of the exterior of a ventral valve from the Upper Ordovician Dalmanitina beds of Få dalaberg, Västergötland, Sweden. Dalmans figure of *L. rugosa* (1828, pl. 1, fig. 1) was evidently based on this specimen and nr. Br. 10446, the cast of the exterior of a dorsal valve from the same horizon at Besstorp, Mösseberg, Västergötland. Both specimens were, according to the labels, collected by Dalman in 1827. They have both the dimensions given by Dalman for this species (Width 44 mm, length 24 mm).

Description: Moderately large species with about 7—11 strong. evenly concentric rugae, and a sharply elevated ridge around the disc, The radial sculpture is fine, and undifferentiated. The convexity of the disc is strong near the apex, and flattens out posteriorly. The geniculated fringe is long, almost as long as half the disc, and with an angle of geniculation about 120° or more. The cardinal angle is very sharp, and the areas are rather low.

Ventral interior (pl. 7, figs. 1—2) with flabellate muscle impressions with several radial ridges. Adductor muscle impressions small, placed anteriorly. Pedicle foramen wide. Teeth strong, pseudodeltidium unknown. The concentric rugae can also be seen on the inner surface of the valves.

Dorsal interior badly known. The cardinal processes seem to be elongate and diverging, and the chilidium is unknown. The muscle impressions are weak, and rather small. It has not been possible to determine if they are circular, as in the younger species, or if they were elongate bilobed as in some older species.

The shell-structure is coarsely pseudopunctate, the puncta, however, are not so large as in *L. depressa* and many other *Leptaena* species.

Remarks: *L. rugosa* differs from most Silurian Leptaenas in the shape of the ventral muscle impressions, and from most of the Ordovician ones in the strong concentric rugae, the high geniculated ridge around the disc, and in the blunt angle between the geniculated fringe and the disc. Its nearest relatives seem to be some species described by BANCROFT MS (1949) from the British Llandovery. None of these species seem to be strictly synonymous with *rugosa*. They all have elongate muscle impressions which are well defined laterally.

Distribution: *L. rugosa* is found only in the uppermost Ordovician of Scandinavia. Some specimens which might be referred to it, or a very similar species are found in the Upper Ordovician in Belgium.

Leptaena (?) *indigena* sp. n.

Pl. 10, figs. 10—11, textfigs. 38A, 39 G.

Type data: The holotype, PMO 67013, is the cast of a ventral interior from the Coelosphaeridium beds at Brattberg, Ringsaker district.

Material: 6 ventral interiors, one fragmentary dorsal one, and a number of casts of the exterior.

Diagnosis: Large *Leptaena* species, with long hinge-line and sharp cardinal angles, clearly bounded ventral muscle impressions, and *Kiaeromena*-like dorsal interior.

Description: A rather large species, the holotype is 44 mm wide and 23 mm long, which is slightly less than the average size. The valves are abruptly geniculated, the ventral disc is flat, with fine, irregular concentric rugae. The moderately convex geniculated fringe is long, generally just as long as the disc, or even longer. The lateral flanks of the valves are long, and flat. The radial sculpture is comparatively fine, and distinctly differentiated.

The ventral interior show strong teeth, large muscle impressions, which are distinctly bordered, and bluntly pointed posteriorly. The adductors are badly defined. The vascular system can not be seen.

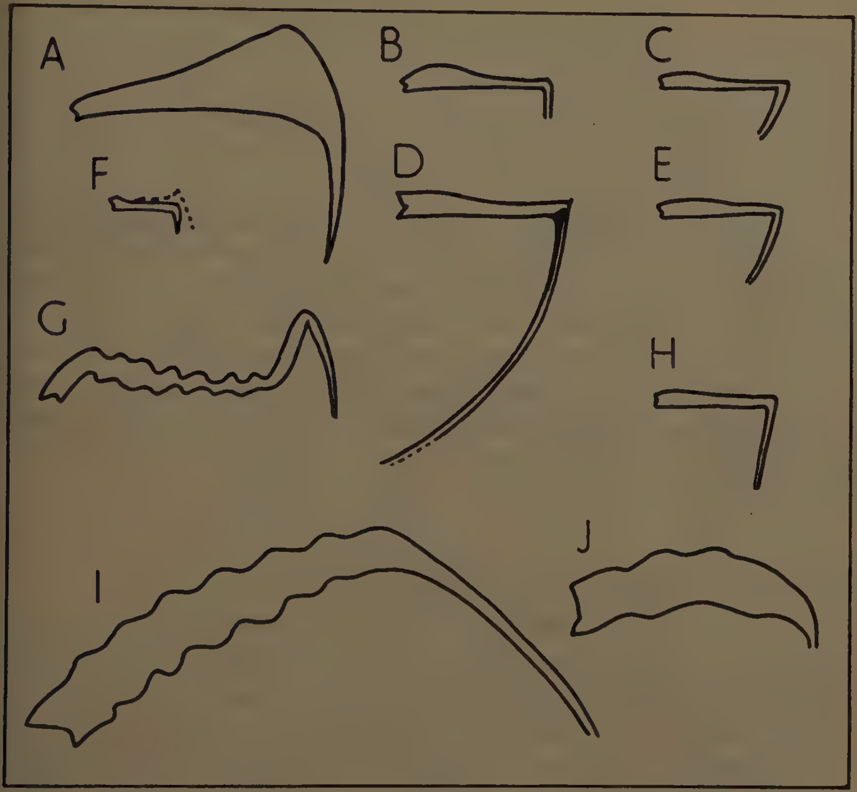

Fig. 38. *Cross-sections of species of Leptaena* and *Kiaeromena.* 9/10th of natural size. A. *L.* (?) *indigena* sp. n. from the Coelosphaeridium Beds in the Ringsaker district. B, D, E, *L. strandi* sp. n. B. A typical and D. a highly gerontic specimen with very long fringe, and high areas. both from the Cyclocrinus (?) Beds of the Hadeland district. E. is a typical specimen from zone 4bγ, just north of Hvalstad in the Asker district. C. *L. veldrensis* sp. n. from the Coelosphaeridium Beds of the Ringsaker district. F. *L. minuta* (KIÆR 1926) from the Sphaeronid Shale in the Hadeland district. The dotted line show a section through the raised edge of the median sulcus. G. *L. rugosa* DALMAN, from the Dalmanitina zone of Vestergötland, Sweden, to show the difference between this species and the Norwegian, Middle Ordovician ones. H. *L. ennessbe* sp. n. from zone 4bα at Billingstad, Asker district. I. *Kiaeromena kjerulfi* (HOLTEDAHL 1916) from zone 4bβ at Lindøya, Oslo district. *J. Kiaeromena* cf. *juvenilis* (ÖPIK 1930) from the Coelosphaeridium Beds at Brattberg, Ringsaker district.

The dorsal interior shows two strong parallel cardinal processes, circular, well defined adductor muscle impressions, and three septa posterior to the muscle impressions.

The shell-structure is unknown, but it is supposed to be coarsely pseudopunctate as in the other Leptaenas because of the strong pustules found in the interiors.

This species differs from all other Ordovician Leptaenas in the dorsal interior, which is similar to that of *Kiaeromena*. It differs from that genus in sculpture and geniculation. *L. indigena* seems to be intermediate between *Leptaena* and *Kiaeromena*. It resembles the latter genus also in the differentiated sculpture.

Distribution: L. indigena is found in the Coelosphaeridium beds in the Ringsaker district only. Some fragmentary casts from the same horizon in the Toten district may also belong to the same species.

Leptaena strandi sp. n.

Pl. 10, figs. 4—5, textfigs, 38BDE, 39D.

Type data: The holotype, PMO 67019, is the cast of a ventral interior from zone 4b*γ* at Billingstad, Asker district.

Material: 14 ventral and 2 fragmentary dorsal interiors, and a large number of complete specimens and valves.

Diagnosis: Leptaena species with abrupt geniculation with no elevated ridge around the disc. Angle between the fringe and disc about 90°, or slightly less. Ventral muscle impressions broad, short, radially striated and well defined.

Description: Species of moderate size, the holotype, which is rather small, is 20 mm wide and 9 mm long. The discs are almost parallel, and with no elevated ridge, except in very large, gerontic specimens. The geniculated fringe is curved, the angle between it and the disc is 90°, or less, in some gerontic specimens the fringe is longer than the disc, and in one specimen (textfig. 38 D) the marginal part of the fringe is almost parallel to the disc. It is an interesting, but unsolved problem how the animal managed to open and close shells with this structure. The sculpture is undifferentiated, with a few, irregular concentric wrinkles. The areas are comparatively high.

The ventral interior shows strongly defined, broad, short muscle impressions bordered by a somewhat irregular ridge, and with a badly defined, short median septum. The adductors are small, and well defined, bordered by thin ridges. The diductors are radially striated. A distinct ovarian impression is found in most old specimens. The teeth are strong, and so are the dental plates, which diverge at about 120°. The pedicle foramen was very small, and the pseudodeltidium has not been seen.

The dorsal interiors are badly known, the cardinal processes are unknown, and the muscle impressions appear to be bilobed.

Some specimens from older horizons, especially zone 4bα at Gomnes—Rud, Ringerike district may also belong to this species. The ventral muscle impressions are smaller, and less defined than in the typical specimens, the teeth are also smaller. Because of the limited material, it is impossible to decide if these specimens, which resembles young ones of *L. strandi*, belong to this species. They are widely different from the contemporaneous *L. ennessbe.*

The shell structure is coarsely pseudopunctate, with puncta of uniform size all over the valves. The puncta seem to be smaller in the older specimens than in the younger ones.

Remarks: This species differs from the other members of *Leptaena* in the shape of the ventral muscle impressions, and the angle of geniculation. The muscle impressions, and possibly the dorsal interior is similar to that of *L. rugosa*, which, however, has a different geniculation (textfig. 38 B, C, D, G).

Distribution: In zone 4bγ in the Oslo—Asker, district and the Cyclocrinus beds in the northern part of the Hadeland district. Specimens which can not be distinguished from this species exteriorly, occur abundantly in the Mastopora beds in the Langesund—Gjerpen district. As mentioned above, there are some specimens from zone 4bα in the Ringerike district, which also might belong to this species.

Leptaena ennessbe sp. n.

Pl. 10, fig. 9, textfig. 38 H.

Type data: The holotype, PMO 67016, is the cast of a ventral interior from the upper part of zone 4bα at Billingstad, Asker district.

Material: 6 ventral interiors and a number of valves and casts of valves.

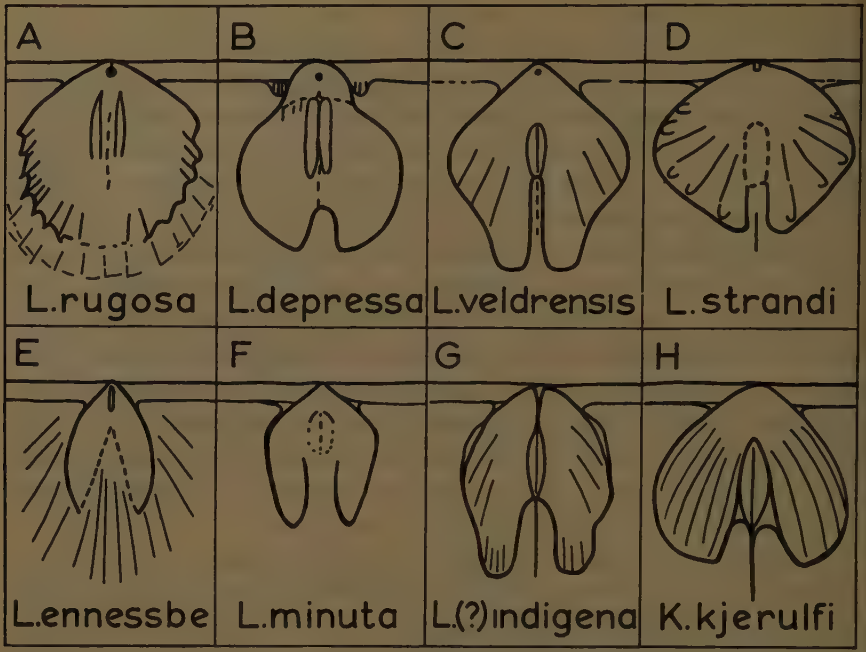

Fig. 39. Ventral interior of species of *Leptaena*. A. *L. rugosa* DALMAN, from the Dalmanitina zone at Mösseberg, Vestergötland, Sweden. B. *L. depressa*, (SOWERBY, em. POULSEN 1943) from the Mulde Marl (Upper Wenlock) at Fröjel, Gotland, Sweden. C. *L. veldrensis* sp. n., from the Coelosphaeridium Beds of the Ringsaker district. D. *L. strandi* sp. n., from the Cyclocrinus beds (?) of the Hadeland district. E. *L. ennessbe* sp. n. from zone 4bα, at Billingstad, Asker district. F. *L. minuta* KIÆR 1926, from the Sphaeronid Shale, Tønnerud-odden, Hadeland district. G. *L.* (?) *indigena* sp. n. from the Coelosphaeridium Beds of the Ringsaker district. H. *Kiaeromena kjerulfi* (HOLTEDAHL 1916), from zone 4bβ, in the Oslo—Asker distriot. The figures are drawn to show the same size of the disc, and the relative size of the muscle impressions.

Diagnosis: Leptaena-species with abrupt geniculation with no elevated ridge around the disc. Angle between the disc and the fringe less than 90°. Ventral muscle impressions small, badly defined, with low, straigth lateral ridges. Large pedicle foramen, with pedicle almost parallel to the disc. Strong ventral umbonal convexity, otherwise flat discs.

Description: Comparatively small species, the holotype is 20 mm wide, and 11 mm long. Sculpture coarse, undifferentiated. There are usually a few broad, irregular concentric rugae. The discs are flat except for a strong ventral umbonal convexity, which is connected with the pedicle foramen, directed almost parallel to the disc. The geniculation is abrupt, the angle is less than 90°, and the usually long fringe is curved.

The ventral interior shows small teeth, high, thin dental plates, small, badly defined ventral muscle impressions, bounded by low, converging straight lateral ridges. No adductor impressions are defined, the opening between the posterior ends of the diductors is coarsely striated, just as the rest of the interior. The pedicle foramen and pedicle furrow is long and prominent.

The dorsal interior is unknown, and the shell-structure is coarsely pseudopunctate.

Remarks: This species differs from the younger members of the genus in the weakly developed ventral interior, which must be regarded as a primitive feature. The strongly developed pedicle and the direction of the pedicle is peculiar for this species.

Distribution: In zone 4bα in the Oslo—Asker district, and in the lower part of the Coelosphaeridium beds in the Ringsaker district. The presence in the latter district, might indicate that the species is an ecological type of *L. veldrensis*. The specimens of *L. ennessbe* occur in the same sediment (dark mudstones) in both districts, whereas *L. veldrensis* is restricted to siltstones and muddy siltstones.

Leptaena veldrensis sp. n.

Pl. 10, figs. 6—8, textfigs. 38C, 39C.

Type data: The holotype, PMO 67017, is the cast of a ventral valve from the Coelosphaeridium beds at Bratberg, Ringsaker district.

Material: 5 ventral and 4 dorsal interiors, and a number of casts of exteriors.

Diagnosis: *Leptaena* species with abrupt geniculation, with elevated ridge around the disc in old specimens only. The ventral muscle impressions are prolonged posteriorly, and the valves are much wider than long.

Description: A wide, narrow species, the holotype is 26 mm wide and 10 mm long. There is no elevated ridge in the ventral valve, but a low, rounded one in the dorsal. The fringe is generally shorter than the disc. The areas are low, and meet at about 90° in adult specimens. The sculpture consists of comparatively fine, undifferentiated ribs, and there are only a few, indistinct concentric rugae.

The ventral interior shows the long diductor impressions, short. well defined adductors, placed far back, and a very high and prominent median septum. The teeth are strong, and the dental plates short. The vascula are deeply impressed around the ovaria, which are not divided by the median vascula in the present specimens.

The dorsal interior shows small, diverging cardinal processes, a smooth chilidium with a median fold, and strong socket plates. The muscle impressions are strong, bilobed, just as in the *Oslomena*. There is also a median septum. In the youngest dorsal interior present, Pl. 10, fig. 8, the muscle impressions are not well defined, and the socket plates are thinner. The ridge around the dorsal disc, which generally is prominent in this species, is also absent in the young specimen.

The shell structure is pseudopunctate, with the puncta decreasing slightly in size towards the margin.

Remarks: This species differs from the other Middle Ordovician Leptaenas in the long ventral diductor impressions, and in the proportions of the valves. The young specimens, and the specimens from the Langesund—Gjerpen district differ from *Hedstroemina* chiefly in the elevated ridge around the dorsal disc.

Distribution: In the Coelosphaeridium beds in the Ringsaker district, and in the Mastopora beds and the upper part of the Bryozoan beds in the Langesund—Gjerpen district. In the latter district, the specimens resemble the young specimens in the Ringsaker district, probably due to different ecology (supply of lime).

Leptaena minuta KIÆR 1926.

Pl. 7, figs. 6—8, textfigs. 38 F, 39 F.

1926 *Leptana minuta* sp. n. — KIÆR, pp. 9—10, textfig 3a—b.

Type data: The lectotype is PMO 34716, a ventral valve showing the exterior, from the Upper Cyclocrinus beds at Tønnerudodden, northern part of the Hadeland district. The lectotype is the specimen figured by KIÆR (1926, textfig. 3a—b) and in this paper, pl. 7, fig. 7.

Material: 4 dorsal and 6 ventral interiors, and a moderate number (about 20) valves and casts of valves.

Description: A very small species, the lectotype is 10 mm wide and 5,5 mm long. The areas a e moderately high, and almost in the same plane. the discs are flat, with distinct umbonal swellings, largest in the ventral. The geniculation is abrupt, at about 100°, and the fringe is not curved longitudinally. There is a strong sinus, with vertical axis. In the ventral valve, the edges of the disc are raised on both sides of the sinus. In the rest of the ventral valve, and in the dorsal, there is no elevated edges around the disc. The sculpture consists of comparatively strong equal-sized ribs, and no or very few and weak rugae.

The ventral interior shows small teeth, well defined muscle impressions bordered by widely diverging (120°) dental plates, and long, slightly converging lateral ridges. A short, broad median septum is found between the posterior ends of the muscle impressions. The adductors are comparatively large, and placed in the middle of the diductors. The pedicle foramen which is small, has not been seen in all specimens. In a gerontic specimen (pl. 7, fig. 6), the lateral ridges and the dental plates are not connected, and a vascular ridge is developed around the ovaria. The vascular system itself is not well developed. It appears to be the same as of the other Leptaenas.

The dorsal interior shows extremely small cardinal processes, which are placed far anteriorly, and thin, short socket plates, In some specimens the muscle impressions are developed, and there is a median septum, just as in species of *Rafinesquina.*

The shell structure is densely pseudopunctate, with large puncta near the muscle impressions, and smaller ones towards the margin.

The cardinal processes are placed in a depression, which is reflected on the exterior of the valve.

Remarks: This species is easily distinguished from all other Leptaenas because of the sinus, and the dorsal interior. The latter is rather like that of *Rafinesquina,* which, however, lacks the depression, and also generally has pseudopuncta of nearly equal size all over the valve. The straight converging lateral ridges in the ventral interior reminds one of the genus *Mjoesina,* which differs considerably in shape. Several other species of *Leptaena* have a similar structure of the ventral muscle impressions.

Distribution: *L. minuta* is known only from the type locality, where it seems to occur abundantly.

Leptaena cf. *minuta* KIÆR

Material: Two casts of the ventral interior, and a few casts of the exterior.

Description: The specimens are small, and have an abrupt geniculation, with no sinus, or a weak one. The sculpture is similar to that of the typical *L. minuta.*

The ventral interiors, which are badly preserved, seem to correspond to those of *L. minuta* in all details. The dorsal interior and the shell structure is not known.

Remarks: From what is known of it, this species only differs from *L. minuta* in the absence of the sinus. Some specimens have a slight indication of a sinus, and it is possible that the presence of this feature is a function of the ecology, which is different in the localities in which the two types are found. In any case, the material present is too fragmentary to allow a description of a new species. It must be mentioned that the specimens referred to here are from somewhat older beds than the typical *L. minuta.*

Distribution: In the Echinosphaerites and the lower part of the Bryozoan beds in the Langesund—Gjerpen district.

Leptaena sp.

Pl. 7, fig. 13.

Two deviating dorsal interiors of an imperfectly known *Leptaena* species have been found. The first one (pl. 7, fig. 13) is an excellently preserved cast from the lower part of the Coelosphaeridium beds in the Ringsaker district, and the other, fragmentary specimen comes from zone 4bα at Stubdal, Ringerike district. The valves are rectangular, 17 mm wide and 10,5 mm long, with a short geniculation at about 90° to the disc, which is surrounded by a rounded edge. The area is high, and the cardinal processes are large, almost parallel plates. The rather strong socket plates diverge at about 100°. The large muscle impressions are bilobed, just as in *Oslomena,* and there is also a thin median septum. The chilidium is not observed. The vascular system is well defined marginally, and seems to be of the same type as that of *Oepikina* rather than that of *Leptaena.*

The cardinal processes are asymmetrical in both specimens, but this might be accidental.

Remarks: The present species differs from the other Middle Ordovician Leptaenas in the rectangular shape, which is found in a number of Silurian species. The muscle impressions are like those of *Oepikina* and *Oslomena*, from which the present species differs in the cardinal processes, and in having an elevated ridge around the disc. It is remarkable that the species is among the oldest ones recorded, only *L. ennessbe* is contemporaneous.

Kiaeromena gen. nov.

Type species: Leptaena kjerulfi HOLTEDAHL 1916, pp. 72—73, pl. 13, figs. 9—11.

Diagnosis: Strophomeninid genus with large, dorsally deflected valves, generally without distinct geniculation. Broad, flabellate, well defined ventral muscle impressions, with the adductors in the same place as in *Leptaena*. The dorsal muscle impressions are generally well defined, circular or slightly bilobed. The cardinal processes are strong, with characteristic muscle attachments. The pseudodeltidium is large and massive, and the chilidium is thin.

Description: The interior of this genus reminds one of *Leptaena*, especially its Silurian species. It is more highly developed than most contemporaneous Leptaenas. It differs from that genus in the exterior, which is not abruptly geniculated, and very coarsely rugated. The pseudodeltidium is also much larger than in *Leptaena*.

Besides the type species, *Kiaeromena* includes the following species: *K. juvenilis* (ÖPIK 1930), *K. esthonensis* (BEKKER 1921)[1], and *K. richmondensis* (FOERSTE 1909). The latter species together with *L. indigena* sp. n. and *L. luhi* SOKOLSKAJA 1954 form a gradual transition between *Kiaeromena* and *Leptaena*.

Distribution: Middle Ordovician, and probably lower part of Upper Ordovician.

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[1] This species has been referred to as *Leptaena trigonalis* SCHMIDT 1908 (p. 726 ÖPIK (1930) and SOKOLSKAJA (1954)). *Leptaena trigonalis*, is, however, a nomen nudum, and BEKKERS name has to be used. The reference to «pl. XIII, figs. 150—153» in the list of synonymy given by SOKOLSKAJA (1954, p. 54.) does not refer to SCHMITH 1908, it is taken from ÖPIK 1930, and does therefore not validate the name *trigonalis*.

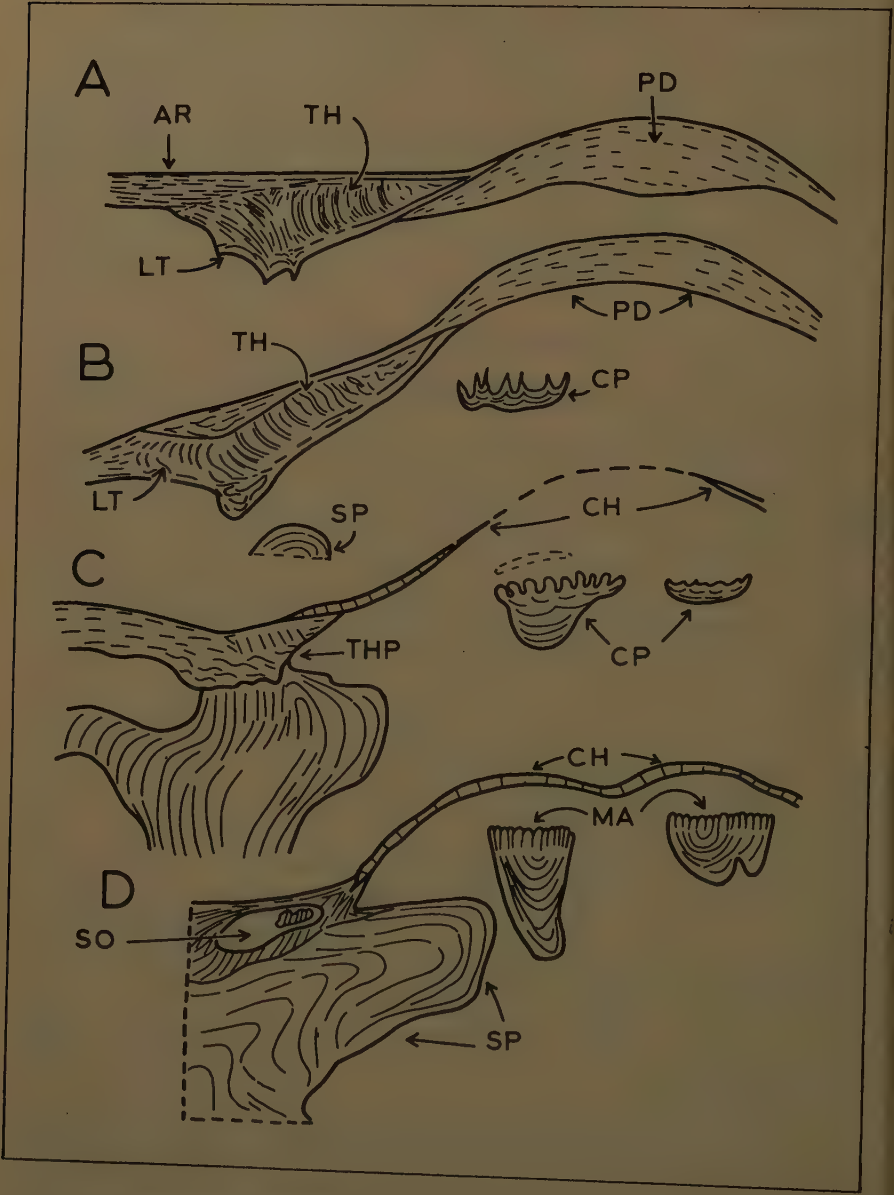

Fig. 40. *Kiaeromena kjerulfi* (HOLTEDAHL 1916). Four horizontal parallel section through a specimen from zone 4bβ at Langåra. Asker district. In C. the border between the tooth and the dorsal valve is obscured due to recrystalliza-

Kiaeromena kjerulfi (HOLTEDAHL 1916).

Pl. 7, figs. 14, 16, pl. 10, figs. 1—3, pl. 14, figs. 2, 9, textfigs. 6C, 38I, 39H, 40—41.
1916 *Leptaena kjerulfi* sp. n. — HOLTEDAHL, pp. 72-73, pl. 13, figs. 9-11.

Type data: The lectotype is PMO L128, a specimen showing the greater part of the dorsal interior, from zone 4bβ at Gåsøya, Oslo—Asker district. The specimen is figured by HOLTEDAHL 1916, pl. 13, fig. 9.

Material: 6 dorsal and 14 ventral interiors, and a large number of valves and complete specimens.

Description: A large species, the lectotype is 70 mm wide and 39 mm long, being a specimen of average size, or slightly larger. The convexity is variable, from specimens with flat disc, and a gently rounded geniculation to specimens which are more evenly convex, with barely visible geniculation. The sculpture consists of coarse, regular and prominent concentric rugae, 9—14 on ordinary specimens. The radial sculpture consists of ribs with 6—8 striae between each. The difference between the ribs and the striae is small, but easily distinguishable. There are very fine growth-lines, similar to those in *Strophomena norvegica*. Irregularities in the sculpture indicating healed fractures are common, in spite of the thick valves (pl. 7, fig. 16, z).

The areas are high, especially the ventral one, and they meet at about 90—120° in ordinary adult specimens. Both the pseudodeltidium, which is very thick and massive, and the thin chilidium, are strongly arched, and almost completely cover the delthyrium and the notothyrium.

The ventral interior shows the well defined muscle impressions, which are broad, with curved sides, and a distinct, low median septum, with the diductor impressions on the anterior end. The teeth are thin, merely thickenings of the strong dental plates. In thin section (textfig. 40 A—B, TH) they are built up of parallel lamellae of fibrous tissue,

tion. Sections A and B are almost completely in the ventral valve, whereas C and D are through the dorsal valve.

Abbreviations: AR — Area. CH — Chilidium. CP — Cardinal processes. LT — Lateral extention of teeth. MA — Muscle attachment on the cardinal processes (cf. textfig. 6). PD — Pseudodeltidium. SO — Sockets. SP — Socket plate. TH — Teeth. THP — Teeth-plate, with diffuse border against the dorsal valve. Magnification: about 8x.

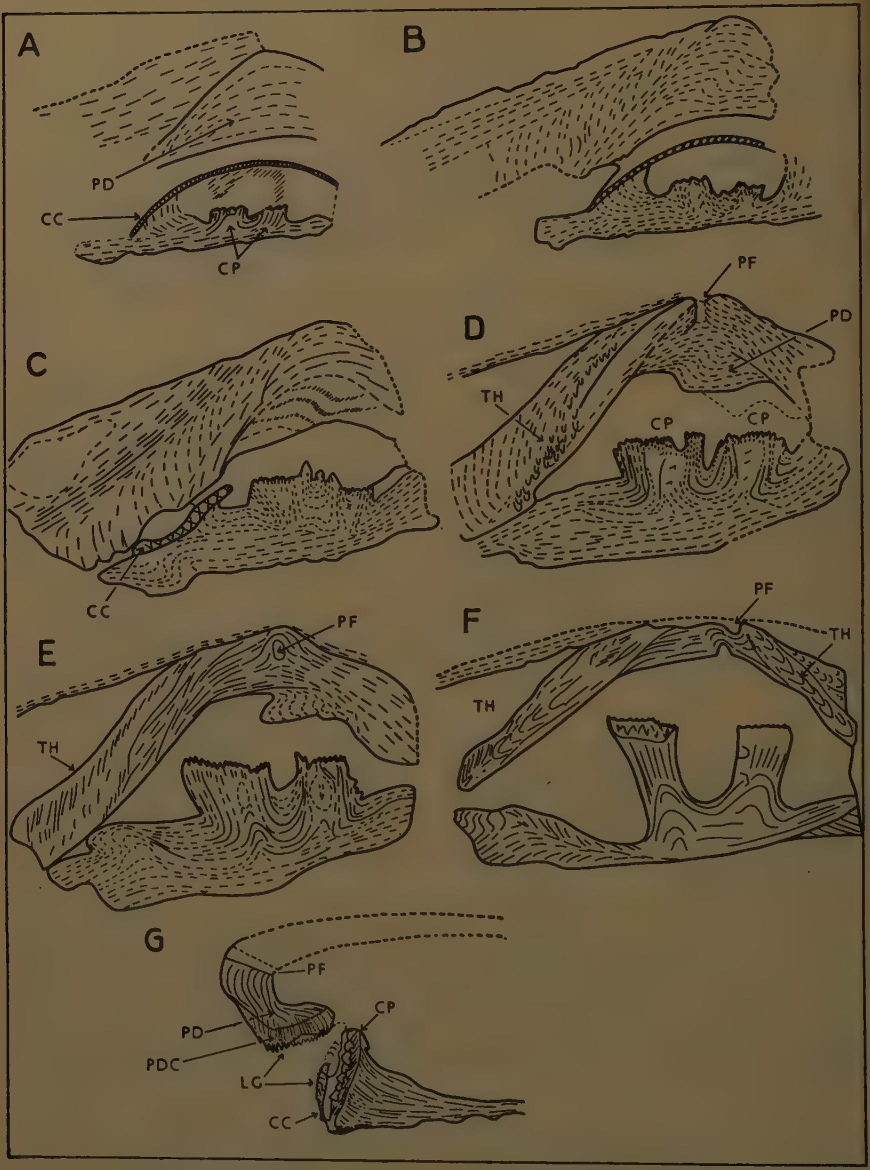

Fig. 41. *Kiaeromena kjerulfi* (HOLTEDAHL). A—F. 6 paralell sections of the central portion of a specimen. G. longitudinal section (incomplete) of another, smaller specimen. Dotted lines indicate reconstructed areas, dotted areas indicate areas colored yellowish-brown. Both specimens are from the middle-upper

which are well differentiated from the rest of the valves. There is always a pedicle foramen, but it is small for a so large species, generally it is less than ½ mm in diameter.

The dorsal interior shows the strongly bounded circular muscle impressions, which seem to have some minor muscle (?) impressions on the posterior end. This might be the other branch of the adductors, found in *Oslomena* and the oldest *Leptaena* species.

In front of the muscle impressions, there are three parallel septa, probably intervascular ones. The socket plates are strong, and the sockets narrow and elongate, corresponding to the shape of the teeth. The cardinal processes are high, vertical, and curved posteriorly. The anterior side is straight, and furrowed by a large number of deep cavities, which are widest near the bottom. These cavities are also found on the upper surface of the processes, and probably served as muscle attachments. No similar structure has been described from other strophomenids. It is only known from this species, and possibly from the other *Kiaeromena* species.

The concentric rugae can be seen also on the interior surface of both valves in spite of their thickness.

The shell structure is comparatively finely pseudopunctate. The structure of the cardinal processes and teeth are described above. The pseudodeltidium and the chilidium have been studied in both vertical and horizontal serial sections (textfigs. 40—41). The latter is a relatively thin plate which in vertical sections (textfig. 41G), and on artificial casts of the exterior show distinct lamellae with the edges turned towards the pseudodeltidium. The tissue of both the latter and the chilidium is yellow-coloured, fibrous and sharply distinguished from the rest of the valve. The pseudodeltidium is a massive block, built up of growth (?) lamellae with edges turned towards the chilidium. Because of these structures, the author believes that this species, as well as others with the same structures, had a ligament, which opened the valves.

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part of zone 4bβ, that shown in A—F is from Steilene, Oslo—Asker district, and that shown in fig. G. is from the SE side of Langåra, Asker distrikt.

Abbreviations: CC = Chilidium. CP = Cardinal process. LG = Supposed attachments for ligament. PD = Pseudodeltidium. PDC = Frontal part of pseudodeltidium, coloured by organic material. PF = Pedicle foramen. TH = Teeth.

Remarks: K. kjerulfi differs from all other species of *Kiaeromena* in size and sculpture. It also differs from *K. richmondensis* (and *Leptaena indigena* and *luhi*) in the absence of a strong geniculation, and from *K. juvenilis* in the dorsal muscle impressions. Because of the large, generally well preserved material, this species is much better known than the other species of *Kiaeromena* and *Leptaena*, especially as regards the histological structure. The reason for these features being mentioned here, is that some of them may possibly be used in the systematics when more species have been studied in detail.

Distribution: This species is the guide-fossil for zone 4bβ in the Oslo—Asker district. It is confined to that zone, and is very common in many localities. Outside the Oslo—Asker district, only one specimen has been found at Bilid, Toten district, mentioned by HOLTEDAHL (1916, p. 73). There is no doubt that the specimen belongs to *K. kjerulfi*, but the preservation and lithology does not resemble that which usually is found in the Toten district. A similar species, *K.* cf. *juvenilis*, is, however, found in contemporaneous layers in the Ringsaker district.

Kiaeromena cf. *juvenilis* (ÖPIK 1930).

Pl. 7, figs. 10—12, textfig. 38J.

Material: Two complete specimens, one showing only the exterior, and one showing both the interiors and exteriors of both valves.

Description: The specimens are comparatively large, the figured one is 26 mm wide and 18 mm long. The valves are roundly geniculated, and have a sculpture consisting of badly differentiated ribs and striae, and a number of broad, concentric rugae, 5 in one specimen and 8 in the other. The distance between the discs (the body-volume) is considerably smaller in the specimen with many rugae (from Asker) than in that from the Ringsaker district.

The ventral interior, which is known only in the specimen from Ringsaker, shows small, well limited muscle impressions, resembling those of *K. kjerulfi* in shape. The adductor muscle impressions are not well defined. The dental plates are strong, but the teeth are thin.

The dorsal interior shows strong cardinal processes, of the same type as in *K. kjerulfi*, and short, high socket plates. The muscle impressions are badly defined, and a transition between septa (branchial)? and muscle impressions seems to occur, just as in *Oslomena osloensis*, and in *K. juvenilis* from the Baltic region. The vascular septa are only faintly indicated. The shell substance is coarsely pseudopunctate.

Remarks: The two specimens indoubtly represent intermediate forms between *K. kjerulfi* and *K. juvenilis*. They are larger than most specimens of *K. juvenilis*, and resemble *K. kjerulfi* in the rounded geniculation and the short fringe. The interiors are more like *K. juvenilis*, which also have the bilobed, septate muscle impressions.

Distribution: One specimen (exterior only) is from the upper part of zone 4bα at Arnestadtangen, Asker district, and the other (both interiors and exteriors) is from the Coelosphaeridium beds at Brattberg, Ringsaker district.

Family Stropheodontidae CASTER 1939 em. WILLIAMS 1953.

Two species undoubtedly belonging to this family are found in the Middle Ordovician of the Oslo region. These are the oldest representatives of the family, and at least one of them is a very primitive one. The possibility of the family being polyphyletic, and the importance of these species in the discussion of that problem, see p. 22.

The present material of these two species is rather limited. More well preserved specimens will probably be found, and then a more detailed description can be given.

Genus *Stropheodonta* HALL 1952.
Subgenus *Eostropheodonta* WILLIAMS 1951.
Stropheodonta (*Eostropheodonta*) *williamsi* sp. n.
Pl. 12, figs. 2—5, textfig. 32A.

Type data: The holotype is PMO 38164, the cast of a dorsal interior from the Cyclocrinus Shale at Furuberget in the Hamar—Nes district.

Material: 5 ventral and 4 dorsal interiors, and a number of casts of the exteriors.

Diagnosis: *Eostropheodonta* species with strong umbonal convexity in both valves, concentric rugae, small dental plates, Socket plates with 5—7 grooves in adults, diverging at about 90°. Dorsal muscle impressions subcircular.

Description: A comparatively large species, the holotype is 33 mm wide and about 23 mm long. The umbonal part is swollen in both valves, so that the specimens have a characteristic longitudinal cross-section (textfig. 32A). The convexity is greatest near the hinge-line, the rest of the valves are flat, or very slightly convex, and with a rounded marginal geniculation. On both sides of the umbo, the valves are relatively flat. The cardinal angles are sharp. The sculpture consists of numerous (8—11) strong and generally continuous rugae, crossed by irregularly differentiated ribs and striae. There is a narrow bundle of stronger median ribs, generally slightly assymmetrical. The areas are low.

The ventral interior shows well defined, comparatively small muscle impressions, which are radially striated up to the apex of the valve, (cf. *S.* (*E.*) *siluriana* (DAV) in WILLIAMS 1951, textfig. 22). The dental plates are strong, short, and with 5—7 prominent, elongate crenulations. The teeth are only slightly developed, the corners between the dental plates and the hinge-line is not elevated, and with practically no deposition of secondary tissue. No pedicle foramen can be seen, and it must have been very small if present at all. There is a pseudodeltidium.

The dorsal interior shows long, blade-like cardinal processes in young specimens, and shorter, thicker ones in older specimens. There is a high chilidium, with a fold corresponding to the slit between the cardinal processes. The muscle impressions in the old specimens are like those in *Rafinesquina*, with an anchor-shaped platform. The sockets are wide, the plates diverging at about 90°, and with grooves, corresponding to the crenulations of the teeth. Because of the preservation of the specimens, these grooves are rarely completely preserved, usually they are found only on one side, and in some cases they were destroyed during preparation. This is the case with the holotype, where the grooves disappeared when a latex cast was made of the specimen. The grooves are visible on the cast, but the soft rock adhered to the latex so that they are no longer clearly visible on the specimen itself, In the young specimens, the crenulations and grooves are not, or only slightly developed.

The rugae can be seen both on the dorsal and ventral interior. Shellstructure unknown.

Remarks: As mentioned above (p. 20) a large number of Strohomenida show more or less vertical striation of the teeth. The specimens present are not more denticulated than many Strophomenas (cf. textfig. 3). This species is included in *Eostropheodonta* because of the cardinalia. WILLIAMS (1951, p. 123) outlined the early development of the Stropheodontids in the following way: «As the stock evolved, so the dental plates migrated towards the hinge-line to lie parallel with it and finally to lose their identity by fusion with the teeth-plates». The cardinal processes are first bladlike, later more disjunct (cf. WILLIAMS 1953, textfig. 2). In *S.* (*E.*) *williamsi* the cardinal processes are longer and more blade-like than in any other Stropheodontid, and the angle of the socket plates (corresponding to that of the dental plates) is about 90°. In the other species of *Eostropheodonta* this angle is 120—150°, and in most other Stropheodontids it is 180° (parallel to the hinge-line). It seems as if *S.* (*E.*) *williamsi* represents an earlier stage in the development of the Stropheodontids, where the migration of the dental (and socket) plates towards the hinge-line has just started. The presence of concentric rugations, geniculation, and the comparatively strong development of the muscle attachments and the median septum distinguishes S. (*E.*) *williamsi* from its congeners (except *S.* (*E.*) *helgoeyensis*), and makes it appear higher developed than them. This stronger development of calcareous tissue might, however, as well be due to ecological differences. The two species described here might, therefore either be specialized, blind offshots of the early Stropheodontids, or they might have given rise to the Upper Ordovician- Early Silurian forms, which look less developed in some features because they lived in a different environment (smaller supply of lime and less favorable condition of living).

If not the crenulations were known, this species would most probably have been referred to *Rafinesquina* (*Hedstroemina*), indicating that it was derived from that subgenus.

Distribution: This species is found in the Coelosphaeridium beds in the Ringsaker district, (localities Bratberg and Fangberget) and in the Upper Cyclocrinus beds in the Hamar—Nes district (locality Furuberget). One can expect to find the species in the Coelosphaeridium beds in the Hamar—Nes district, and in the Cyclocrinus beds in the Ringsaker district, when more material has been collected from these horizons. There is no great difference in the age of the layers in which this species is found.

Stropheodonta (*Eostropheodonta*) *helgoeyensis* sp. n.

Pl. 12, Fig. 6.

Type data: The holotype, PMO 38647, is the cast of a dorsal valve from the upper part of the Mjøsa Limestone at Bergsviken, Helgøya, Hamar—Nes district.

Material: The holotype and a fragmentary cast of a ventral interior, and some fragments of the exterior.

Diagnosis: Well calcified *Eostropheodonta* species with short cardinal processes, socket plates diverging at 120°. The dorsal valve is slightly convex, with a distinct, sharp geniculation, and three intervascular (?) septa.

Description: Sculpture differentiated, 3—5 striae between each rib (the fragments of the exterior, found together with the holotype, might belong to another species). Dorsal valve of moderate size, 24 mm wide and 18 mm long. The cardinal angles are right, and the geniculation is sharp, but irregular. Three subparallel septa (intervascular ?) are found in front of the indistinct, uniformly rounded muscle impressions. Traces of vascular impressions are found along the margin of the valve. Cardinal processes high, short, thin parallel plates united with the strongly diverging socket plates (about 120°). 6—7 grooves on each of them. The area is not completely preserved in the holotype.

The ventral valve is very fragmentary, and the cardinal part is badly preserved, so that the specimen might belong to another species.

Remarks: In the development of the cardinalia, this species is like some Llandoverian species of *Eostropheodonta*, such as *E.* cf. *mullochensis* (WILLIAMS 1951, pl. 8, fig. 3) and *S.* (*E.*) *davidsoni* (HOLTEDAHL 1916, pl. 7, fig. 6, non WILLIAMS 1951). *S.* (*E.*) *helgoeyensis* differs from all congeners in having septa, and a geniculation. Altogether, the species, like *S.* (*E.*) *williamsi* is better calcified than the other members of the subgenus. It differs from the latter species in the greater angle of the socket plates, and in having no concentric rugae.

Distribution: All the specimens are found on the same slab, which comes from the upper part of the Mjøsa Limestone (bed e). It is probably considerably younger than *S.* (*E.*) *williamsi*.

Indet. Strophomenid nr. 1

Pl. 9, Fig. 7.

Material: One dorsal interior and three casts of the exterior.

Description: Exterior resembling *R.* (*H.*) *undata*, but with reversed genicuation. The disc is corrugated by a number of strong rugae, and the radial sculpture is well differentated. The valves appear to be almost parallel. The areas have not been observed.

The dorsal interior, which include only a fragment of the disc, shows small, diverging cardinal processes, an thin chilidum, straight diverging socket plates, and a prominent median septum, thickened posteriorly. The muscle impressions are well defined, and of moderate size. They are cut by a pair of diverging, sharp septa, and the lateral ridges of the muscle impressions are replaced by rows of blunt spines.

Remarks: This species differs from most genera and species known, and the peculiar rows of spines are not known from other Strophomenids. It differs from *Kjerulfina* in the dorsal interior, and from *Strophomena* in the straight socket plates. It differs from *Rafinesquina* in the orientation of the valves.

Distribution: The exact horizon is unknown, it is supposed to be Middle Ordovician. The specimens come from the highly contact metamorphic sediments near Lauervann in the Sandsvær—Eiker district.

Indet. Strophomenid nr. 2.

Material: One fragmentary cast of a ventral (?) exterior from 15,90 m above the lower phosphate bed at Moldekleiv, Langesund—Gjerpen district. (cf. STØRMER 1953, pp. 71—72).

Description: The present specimen is a disc with a slight umbonal convexity, with 6—7 regular, strong concentric rugae. The traces of radial sculpture are weak, but there seems to have been a strong median rib. If a geniculated fringe was present, it has been broken off.

Remarks: This specimen is of course indeterminable as to species and genus. It is mentioned because it occurs at a very low stratigraphical level (zone of *Did. bifidus* or lower part of *Did. geminus*). Very few Strophomenacea are known from this level, and none of them resemble the present specimen. The size, sculpture, and especially the strong submedian rib reminds one of the genus *Inversella* ÖPIK 1933, which occur abundantly in the slightly older beds (zone 3cβ-γ) in the Oslo—Asker district.

Indet. Strophomenid nr. 3.

Pl. 1, Fig. 17.

Material: 4 exteriors and a fragmentary cast of a ventral interior.

Description: The figured specimen, of average size, is 9,5 mm wide and 4.5 mm long. The cardinal angles are right, and the convexity moderate. There is a slight umbonal swelling in the ventral valve. The sculpture consists of 3—5 strong radial ribs with a large number of very fine striae between each, and 7—12 concentric rugae, which are strongest near the hinge-line.

The ventral interior, which is an artificial cast, only shows a small, badly defined muscle impression, the main radial ribs of the external sculpture, and a not denticulated hinge-line.

Remarks: The species most probably belongs to the Plectambonitacea, but it is very difficult to determine the genus. The sculpture reminds one of *Plectambonites* and *Athiella*. The weakly developed interior, and the smooth hinge-line also indicates a relationship with the latter genus. The species referred to *Athiella*, however, are generally more convex, and have a different sculpture.

Distribution: The specimens are found in zone 4aα_1, the beds just above the Orthoceros Limestone (3cγ) at Hamar, Hamar—Nes district.

Trends of evolution in the Strophomenacea.

It is difficult to follow trends of evolution in the Strophomenacea, because of the large number of forms known, and because of the ecological variation of diagnostic features at least in some groups. Probably the Strophomenacea developed from the geologically older Plectambonitacea. It is, however, difficult to trace the subgroup within this superfamily which gave rise to the Strophomenacea. There is also a possibility of the latter superfamily being polyphyletic.

A study of the oldest known Strophomenacea indicates that two lines of development can be traced. The first one, the origin of which is unknown, started with *Kjaerina-Hedstroemina*, and gave rise to the younger Rafinesquinas and most of the Stropheodontids. This line started with species with thin shells, and long, blade-like cardinal processes, and straight, narrowly diverging socket plates (i.a. *«Rafinesquina» llandeiloensis*).

The other line of development started with *Oepikina* and gave rise to *Oslomena*, *Leptaena* and other genera. The early forms had thick valves, branchial septa, bilobed dorsal adductor muscles, and short, often bifurcated cardinal processes.

A number of genera can not at present be placed in any of these lines of development. *Strophomena* possibly belongs to the *Oepikina*-

line, but this has not been proved. It is very difficult to place genera like *Kjerulfina* and *Holtedahlina*.

The *Oepikina*-line is evidently linked with *Christiania* in the development of the branchial septa, even if *Oepikina* is less specialized. Both the cardinal processes of *Christiania oblonga*, and the ontogeny of *C. holtedahli* (described above, p. 117, 124) indicate that the Christiniadae are related to the Leptestids. In *Oepikina* the cardinal processes are related to that of the Sowerbyellinids (textfig. 2 C).

At present it is impossible to divide the family Strophomenidae into two or more subfamilies based on the lines of development referred to here. Only a very careful study on the ontogeny and relative geological age of the oldest members of the family may throw some light on this problem. Until this is done, the author prefers to use the classification of WILLIAMS (1953), with the Leptaenoidina separated as a subfamily.

The relations of the Stropheodontids is not quite clear. WILLIAMS (1950, 1953) believed that the family developed from some primitive Strophomenidae in the end of the Upper Ordovician, and that it was a monophyletic family. He did not mention which primitive Strophomenids he thought was the ancestors, but it is evident from this descriptions that they must have been closely related to *Kjaerina* and *Hedstroemina*, with their long, slender cardinal processes, and more or less widely diverging socket plates.

SCHMIDT (1951) suggested that the family Stropheodontidae was highly polyphyletic. This was, however, partly due to the broad interpretation of the denticulation of the hinge-line advocated by this author. The development of the different types of denticles, and the structure of the teeth, which seem to have formed the base for the development of the Stropheodontid denticulations are described above (p. 20).

The author's observations indicate that the Stropheodontids developed from *Hedstroemina*-like forms, such as suggested by WILLIAMS, but as early as in the Middle Ordovician. Here it must be mentioned that the important diagnostic feature in the family Stropheodontidae are not the crenulated teeth, which are found in a large number of unrelated Strophomenid genera. It is the coalecense of the teeth with the hinge-line which characterises the Stropheodontidae. The value of the crenulated teeth for the articulation of the valves was probably very small, and in any case inferior to that of the cardinal processes, which developed parallel to the teeth, and probably took over their functions as well.

The fact that the histological structure which formed the base for the development of the crenulations is found in the majority of the Strophomenid genera, and the presence of crenulations in gerontic specimens in a large number of different species indicates that the family Stropheodontidae might be polyphyletic. This has, however, not been proved, and the distinct trend of evolution of the teeth in that family is not found in other groups. It therefore seems safe to keep that family distinct from the other Strophomenacea, even if some minor groups, like *Strophonella* might have developed independantly (cf. HOLTEDAHL 1916).

In this paper the family Christianidae WILLIAMS 1953 in included in the Plectambonitacea as a separate family, related to the Sowerbyellinidae. Further studies may show that it should be removed to the Strophomenidae as a subfamily (including the *Oepikina*-group). The family evidently is intermediate between the two superfamilies, and closely related both to the Leptestinids and the *Oepikina*-group of the Strophomenidae. It might also be convenient to restrict the Plectambonitacea to forms with an Orthoid cardinal process, and to include the Sowerbyellidae and the Christianidae either in the Strophomenacea, or in a new superfamily.

Faunal assemblages and correlation.

As mentioned by STØRMER (1953), several different faunal provinces can be discriminated within the Oslo region, and this also applies to the Strophomenidae. The details of the distribution are shown in the tables (p. 200—205). The most prominent faunal provinces are:

1) The Oslo—Asker district, where the Strophomenids show distinct British affinities. Baltic elements in the fauna are few, and occur only in special horizons. The British areas which resemble the Oslo—Asker district, are Northern England, North Wales and Central Eire.
2) The Ringerike—Hadeland districts, with a largely indigenous fauna, with some affinities to Great Britain, especially Shropshire.
3) The Langesund—Gjerpen district, with a definitely Baltic fauna, in spite of the western position of the district.

4) The Hamar—Nes district, with a mixed fauna, with both Baltic, British and indigenous forms.
5) The Ringsaker district, with a mixed Baltic—American fauna.

In the Toten district, and in the Northern part of the Hadeland district the fauna seems to be rather like that found in the two other northern districts, even if the number of common species is small. In the northern districts of the Oslo region, the specimens of Strophomenids seem to be larger than in the other districts, and this applies also to the Toten district. Even species which occur both in southern and northern districts, are generally much larger in the northern ones (cf. p. 54). This might be due to the more littoral character of the northern deposits, and the better supply of oxygen in connection with the rich algal flora.

The other areas in the Oslo region, the Eiker—Sandsvær, Modum and Sjåstad districts seem to be intermediate between the Oslo—Asker and the Langesund—Gjerpen districts. The fauna of the two latter districts is not well known, and that of the Eiker—Sandsvær district have a number of local species, especially Plectambonitacea from the oldest beds.

Because of the striking differences in fauna in the provinces, it is very difficult to correlate the zones of the different districts only with the aid of the Strophomenids. In some cases it is easier to correlate the faunas with more distant ones.

The Baltic elements, which occur especially in the Langesund—Gjerpen and the Mjøsa districts, indicate a correlation of the Coelospaeridium beds and the Echinosphaerites and Bryozoan beds with the Kukruse stage (C 2) in Esthonia. This correlation is also well documented in other animal groups. These beds probably correspond to zones 4bα—β in the Oslo—Asker and Ringerike districts.

The American elements, which are few, and found only in the Ringsaker district, are at least at present of no stratigraphical value.

The british elements, mainly in the Oslo—Asker and Ringerike districts indicate a correlation between the zones with *Bancroftina typa* and *Dalmanella wattsi* and the upper part of zone 4bα (above the bentonite beds, cf. HAGEMANN & SPJELDNÆS 1955). This correlation is supported by a number of common species. (*Eoplectodonta acuminata, Chonetoidea alpha, Sampo oepiki* and others). The correlation between the zone of *Onniella reuschi* and 4bγ is not yet so well documented.

It is difficult to place the zones of the Oslo region in the standard graptolite sequence, especially the zones 4aβ—4bγ. This problem has recently been discussed by JAANUSSON & STRACHAN (1954) and HAGEMANN & SPJELDNÆS (1955). NILSSON (1953) made the important discovery of a mixed graptolite fauna consiting of guide fossil for the zones of *Nemagraptus gracilis* and *Dicranograptus clingani*. This might indicate that the *Nemagraptus gracilis* fauna extends vertically through the *peltifer* and *wilsoni* zones. At present it is therefore difficult to use graptolites in the correlation of this part of the Middle Ordovician, until the graptolite sequence has been revised in detail.

It is also evident that a new stratigraphy could not be based on the Strophomenids only, and since several stratigraphically important groups have not been described from the Oslo region (trilobites, Dalmanellids and bryozoans), no detailed correlations are made in this paper.

The vertical distribution of the faunas is studied especially in the Oslo—Asker district, and the following notes mainly apply to that district.

In zones 4aα_1-$_4$, the Strophomenid fauna is small, consisting only of Plectambonitids. Both in this zone and in 4aβ, all the species seem to be local ones which are not useful for correlation.

In the lower part of zone 4bα, there are few Strophomenida, only Plectambonitids, and only local species. Among the characteristic fossils are *Salopia* spp. and other Orthids. The fauna in the middle part of the zone is not well known, and appears to be poor.

In the upper part of the zone, between and above the bentonite beds, a new and very rich fauna is found. The typical fossils are: *Eoplectodonta acuminata*, *Oslomena osloensis*, *Ptychoglyptus valdari*, *Christiania holtedahli*, and *Nicolella* sp., *Glyptorthis* sp. *Kullervo* sp. and a number of others. This fauna is wide-spread in Great Britain, Eire and Scandinavia. Generally it is found in the top of, or just above the volcanic beds indicating the maximal volcanic activity in the Middle Ordovician (cf. VOGT 1947). A considerable break in the sequence is often found above this fauna (Cf. BANCROFT 1933, HAGEMANN & SPJELDNÆS 1955 and HARPER 1952, who described a graptolite fauna of the *Dicranograptus cligani*-zone just above the fauna mentioned here). The Derfel Limestone fauna, described by WHITTINGTON & WILLIAMS (1955) is rather like this 4bα-fauna, even if no species seem to be common, the fauna is definitely of the same type. The

Derfel Limestone, is, however, succeded by a graptolite fauna of the *Nemagraptus gracilis* zone. Even if the age of the *Nemagraptus gracilis*-fauna is regarded to be uncertain, it seems as if the Derfel Limestone is older than the upper part of 4bα, which have several species in common with the Balclatchie of the Girvan district, and the zones of *Bancroftina typa* and *Dalmanella wattsi* in N. Wales and Shropshire. A possible explanation of this problem is that during the period of maximal volcanic activity, the fauna was destroyed over large areas, especially by ash-falls. The empty space after the destroyed fauna was filled partly with immigration from areas less affected by the volcanism (the Baltic region, the Scottish-American region) and partly by rapid expansion of faunas already accustomed to the «volcanic habiat» (possibly the Derfel Limestone fauna). This might explain the peculiar mixed fauna found in zone 4bα, but there is at present no definite proves for this hypotesis.

In zone 4bβ, a characteristic fauna is found in the Oslo—Asker district consisting of large, generally indigenous forms. The significant ones are *Kiaeromena kjerulfi*, *Eoplectodonta* (?) *percedens*, *Porambonites kjerulfi* n.sp. Outside the Oslo—Asker district, this zone is. not well defined in the fauna or lithology.

In zone 4bγ there are two faunizones, a lower one with a transition to 4bβ, and *Kjerulfina foliovalve*, *Chonetoidea gamma* and *Sowerbyella sericea askerensis* as index fossils. In the Ringerike and Hadeland districts the first and last of these species are represented by nearly related ones. (*Kjerulfina limbata* and *Sowerbyella sericea hadelandica*).

The upper part of the zone has the same Strophomenid fauna as the next younger zone, 4bδ., with *Sampo indentata* and *Kjaerina lepta*. In the lower part of zone 4bδ, *Strophomena* (*Gunnarella*) *delta* and *Eoplectodonta* (?) *rhombica* is added to this fauna.

The uppermost part of zone 4bδ is almost devoid of brachiopods in the Oslo—Asker district. In the Ringerike district, this subzone (4bδ_2, of *Tretaspis kiaeri*) yields *Strophomena* (*Gunnarella*) cf. *rigida* and other fossils which are typical for the overlying Tretaspis Shale (zone 4cα).

The faunizones, of the Strophomenida of the Oslo—Asker district do therefore not in all cases correspond to the stratigraphical units used at present, which are mainly based on the lithology of the beds.

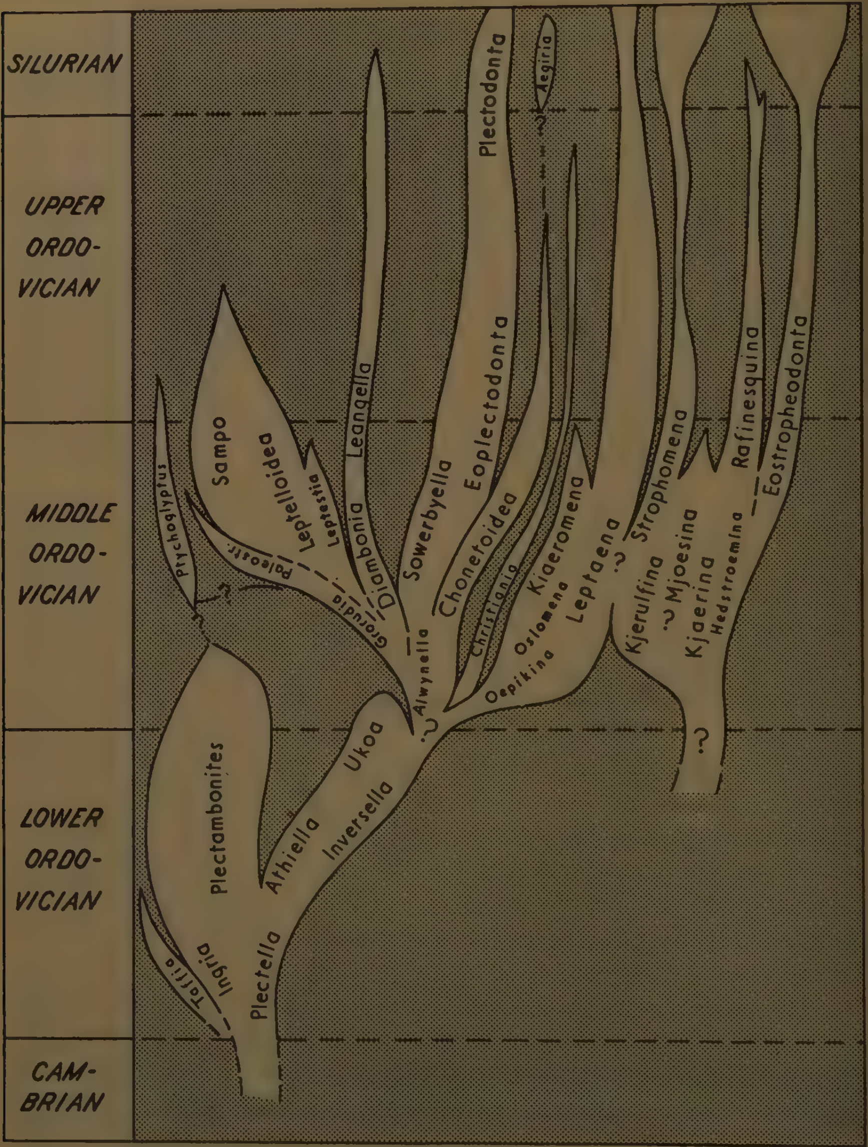

Fig. 42. A diagram illustrating the authors hypothesis of the development of the Strophomenida. Note that the border between the Lower and Middle Ordovician is placed at the base of the *bifidus*-zone, and that between the Middle and Upper Ordovician at the base of the zone with *Pleurograptus linearis*. *Ptychoglyptus* should be firmly united with Paleostr. (= *Paleostropomena*).

SPECIES	ZONES						DISTRICTS									
	aα	aβ	bα	bβ	bγ	bδ	Oslo—Asker	Gj.—Langesund	Eiker—Sandsv.	Ringerike	Hadeland	Toten	Hamar—Nes	Ringsaker		
1) *Ptychoglyptus* valdari	—	—	1	—	—	—	1	—	—	?	?	—	—	—		1
2) *Grorudia* grorudi	—	2	—	—	—	—	2	—	—	—	—	—	—	—		2
3) *Grorudia* (?) glabrata	—	3	3	—	—	—	3	—	—	—	—	—	—	—		3
4) *Paleostrophomena* (?) majori ...	—	—	—	—	—	—	—	4	—	—	—	—	—	—	ec–bz	4
5) *Leptestia* aff. jukesi	—	—	—	—	—	—	—	5	—	—	—	—	—	—	bz	5
Sampo																
6) S. (S.) indentata	—	—	—	—	6	6	6	—	—	?	—	—	—	—		6
7) S. (Leptellina) oepiki	—	—	7	—	—	—	7	—	—	?	7	—	—	—		7
8) S. (Leptellina) elevata	—	—	8	—	—	—	?	—	—	8	—	—	—	—		8
Leptelloidea																
9) L. (Benignites) heintzi	9^3	—	—	—	—	—	—	—	9	—	—	—	—	—		9
10) L. (s.l.) rosendahli	—	—	—	—	—	—	—	—	—	—	—	—	—	10	cø	10
11) L. (s.l.) sp.	11^4	11	—	—	—	—	—	—	11	—	—	—	—	—		11
12) *Diambonia* (?) leifi	—	—	—	—	—	—	—	12	—	—	—	—	—	—	bz–ma	12
13) *Diambonia* anatoli	—	—	13	—	—	—	13	—	—	—	—	—	—	—		13
14) *Leangella* bamari.............	—	—	—	—	—	—	—	—	—	—	—	—	14	—	cy	14
Alwynella																
15) A. osloensis	—	15	—	—	—	—	15	?	—	15	?	—	—	—		15
16) A. intermedia	16^4	16	—	—	—	—	16	—	—	—	—	—	—	—		16
17) A. ildjernensis	17^{2-4}	—	—	—	—	—	—	17	—	17	—	—	—	—		17
Sowerbyella																
18) S. sericea soudleyensis	—	—	—	—	—	—	—	—	—	—	18	18	18	—	cy	18

19) S. sericea askerensis	—	—	—	—	19	—	19	—	—	—	—	—	—	—		19
20) S. sericea hadelandica	—	—	?	—	—	—	—	—	—	—	20	—	—	—	Lcy	20
21) S. ringsakerensis	—	—	—	—	—	—	—	?	—	—	—	—	—	21	cø, en	21
22) S. (?) sp.	—	—	—	—	22	—	—	—	—	22	—	—	—	—		22
Eoplectodonta																
23) E. acuminata	—	—	23	—	—	—	23	—	—	?	?	—	—	—		23
24) E. karina	—	—	24	—	—	—	24	—	—	?	?	—	—	—		24
25) E. (?) percedens	—	—	25	25	—	—	25	25	—	25	—	—	—	—		25
26) E. (?) rhombica	—	—	—	—	—	26	26	—	—	—	26	—	—	—		26
Chonetoidea																
27) C. gamma	—	—	—	—	27	—	27	—	—	—	27	—	—	—		27
28) C. alpha	—	—	28	—	—	—	28	—	—	—	—	—	—	—		28
29) C. stoermeri	29^3	—	—	—	—	—	29	—	—	—	—	—	—	—		29
Christiania																
30) C. holtedahli	—	—	30	—	—	—	30	30	30	30	30	30	—	30	cø	30
31) C. cf. holtedahli	—	—	31	—	—	—	—	—	—	31	—	—	—	—		31
32) C. oblonga	32^{1-2}	—	—	—	—	—	—	—	32	—	—	—	—	—		32
33) C. cf. oblonga	—	33	—	—	—	—	33	—	—	—	—	—	—	—		33
34) C. elongata	34^4	34	34	—	—	—	34	—	34	34	—	—	—	—		34
Rafinesquina																
35) R. (Rafinesquina) sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	35	cø	35
36) R. (Kjaerina) lepta	—	—	—	—	36	36	36	—	—	?	?	—	—	—		36
37) R. (Hedstroemina) holtedahli ..	—	—	37	37	—	—	—	—	—	37	—	—	—	—		37
38) R. (Hedstroemina) ungula	—	—	38	38	—	—	—	—	—	38	—	—	?	—	cy ?	38
39) R. (Hedstroemina) cf. robusta..	—	—	—	—	—	—	—	—	—	—	—	—	—	39	cø	39
40) R. (Hedstroemina) aff. robusta .	—	—	—	—	—	—	—	—	—	—	—	—	—	40	cø	40
41) R. (Hedstroemina) muensteri ..	—	—	41	41	—	—	—	—	—	41	—	—	—	—		41
42) «R». ringerikensis	—	—	42	42	—	—	—	—	—	42	—	—	—	—		42
Mjoesina																
43) M. mjoesensis	—	—	—	—	—	—	—	—	—	—	43	—	43	—	cy–mk	43
44) M. cf. mjoesensis	—	—	—	—	—	—	—	—	—	—	—	—	—	44	cø	44

SPECIES	ZONES						DISTRICTS									
	aα	aβ	bα	bβ	bγ	bδ	Oslo—Asker	Gj.—Langesund	Eiker—Sandsv.	Ringerike	Hadeland	Toten	Hamar—Nes	Ringsaker		
45) M. gregaria	—	—	—	—	—	—	—	—	—	—	—	45	?	—	cø	45
Strophomena																
46) S. norvegica	—	—	46	46	—	—	46	—	—	46	46	—	—	—	cy?	46
47) S. hirsuta	—	—	—	—	—	—	—	—	—	—	—	—	—	47	cø	47
48) S. keilhaui	—	—	—	—	—	—	—	—	—	—	—	—48—		—	cy	48
49) S. steinari	—	—	—	—	—	—	—	—	—	—	—	—	—	49	cø	49
50) S. sp.	—	—	—	—	—	50^2	—	—	—	50	—	—	—	—		50
51) S. (Gunnarella) delta	—	—	—	—	—	51	51	—	—	—	—	—	—	—		51
52) S. (Gunnarella) beta	—	—	—	52	—	—	?	—	—	52	52	—	—	—		52
53) S. (Gunnarella) alpha	—	—	53	—	—	—	53	53	—	—	53	—	—	—	ec; cy	53
54) S. (Gunnarella) cf. rigida	—	—	—	—	—	54^2	—	—	—	54	—	—	—	—		54
Kjerulfina																
55) K. foliovalve	—	—	—	—	55	—	55	—	—	?	?	—	—	—		55
56) K. limbata	—	—	—	—	56	—	?	—	—	56	?	—	—	—		56
57) K. broeggeri	—	—	57	57	—	—	?	—	—	57	—	—	—	—		57
58) K. lata	—	—	58	—	—	—	58	—	—	—	—	—	—	—		58
59) K. (?) sp.	—	—	—	—	—	—	—	59	—	—	—	—	—	—	bz	59
Oslomena																
60) O. osloensis	—	—	60	60	—	—	60	—	—	60	?	60	—	—	cø	60
61) O. celtica (?)	—	—	—	—	—	—	—	61	—	—	—	—	—	—	ec	61
62) O. aff. girvanensis	—	—	—	62	—	—	—	—	—	62	—	—	—	—		62

63)	O. (?) papilio	—	—	—	—	—	—	—	—	—	—	—	63	—	—	cy?	63
	Oepikina																
64)	O. dorsata media	—	—	—	—	—	—	—	64	—	—	—	64	—	64	cø, bz, ms	64
65)	O. (? or Rafinesquina) sp.	—	65	65	—	—	—	65s	—	—	—	—	—	—			65
	Leptaena																
66)	L. (?) indigena	—	—	—	—	—	—	—	—	—	—	—	?	—	66	cø	66
67)	L. strandi	—	—	67	67	67	—	67	67	—	67	67	—	—	—	ma, cy	67
68)	L. ennessbe	—	—	68	—	—	—	68	—	—	—	—	—	—	68	cø	68
69)	L. veldrensis	—	—	—	—	—	—	—	69	—	—	—	—	—	69	bz, cø, ms	69
70)	L. minuta	—	—	—	—	—	—	—	—	—	—	70	—	—	—	Ucy	70
71)	L. cf. minuta	—	—	—	—	—	—	—	71	—	—	—	—	—	—	ec–bz	71
72)	L. sp.	—	—	72	—	—	—	72	—	—	—	—	—	—	72	cø	72
	Kiaeromena																
73)	K. kjerulfi	—	—	—	73	—	—	73	—	—	—	—	73	—	—		73
74)	K. cf. juvenilis	—	—	74	—	—	—	74	—	—	—	—	—	—	74	cø	74
	Stropheodonta																
75)	S. (Eostropheod.) williamsi	—	—	—	—	—	—	—	—	—	—	—	—	75	75	cø–cy	75
76)	S. (Eostropheod.) helgoeyensis	—	—	—	—	—	—	—	—	—	—	—	—	—	76	mk	76
77)	Indet. Strophomenid nr. 1	—	—	—	—	—	—	—	—	77	—	—	—	—	—	hor.?	77
78)	Indet. Strophomenid nr. 2	78^{1-2}	—	—	—	—	—	—	78	—	—	—	—	—	—		78
79)	Indet. Strophomenid nr. 3	79^1	—	—	—	—	—	—	—	—	—	—	—	79	—		79

Abbreviations: In the a*a*-column, the upper figures (i.a. 9^3) indicate the subzone (-s) in which the species occur. In the bδ-column, n^2 indicates that the species is found in subzone 4bδ_2, of *Tretaspis kiaeri*. For the districts where the ordinary stratigraphical symbols are not in use, the last column in the table shows the stratigraphical distribution of the species. cø = Coelosphaeridium beds, cy = Cyclocrinus beds (L = lower, U = upper part), mk = Mjøsa Limestone, ec = Echinosphaerites beds, bz = Bryozoan beds, ma = Mastopora beds, ek = Encrinite Limestone.

A n^s in the Oslo—Asker column indicate that the species is found in the Sjåstad district only. (for stratigraphical terms and boundaries of the districts, see STØRMER 1953).

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[1] Subsequent authors (i. a. WILLIAMS 1951, p. 86) have regarded this paper invalid because it is not legally published according to the rulings of the International Commision on Zoological Nomenclature (Bull. Zool. Nomencl. *4*, p. 146, case 19b). This rule, however, did not attain legal force until May 25th 1950, when it was published (cf. Bull. Zool. Nomencl. *4*, p. 57, case 8, and pp. vii—viii) Since the disputed paper was published in May 1949, the present rules cannot be applied to it, and it must be invalidated according to the rulings legal at the time of publication.

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ADDENDUM

Since this paper was submitted to printing, three important papers have arrived, which have to be mentioned here because they have some influence on the results given by the author.

1) ОРАСПЫЛЬД, А.. Л1956. Новые брахиопоы йыхвиского, кейлаского и вазалеммаского горизонтов. Тр. Инст. Геол. АН Зст. С̱СР т. I сТр. 41 — 67 табл. I—IV.

Some of the species described in that paper are nearly related to some of those found in this paper. *Leptaena taxilla* is probably identical with *L. indigena*, *L. rugosoides* is related to *L. veldrensis*. *L. fluviatilis* might be a *Hedstroemina*, related to one of the species described in this paper. *Actinomena occidens* resemble *Strophomena steinari* both in shape and size, but a closer examination is necessary to determine if they are synonyms. *Holtedahlina sakuensis* and *rakverensis* belong to the same group of species as *Oslomena* (?) *papilio*, and they all definitely belong to *Holtedahlina*.

The relationships mentioned here show that the baltic affinities of the Middle Ordovician Strophomenids of the Mjøsa districts were even stronger than supposed when this paper was written.

2) Williams, A. 1956: The Calcareous Shell of the Brachiopoda and its Importance to their Classification. Biol.Reviews *31*, pp. 243—287. Cambridge.

This is a very important paper, which describes the anatomical base of the features used in the classification of fossil brachiopods, together with a detailed and instructive comparison between living and fossil forms. The taxonomic value of the different morphological features are critically discussed, and even if most of his conclutions are negative, this paper will probably form the base of future discussions of the taxonomy and phylogeny of fossil brachiopods, and will also induce new studies on anatomical subjects.

As mentioned by Williams, the author has expressed deviating views on some points (p. 251, structure of the pseudopuncta = taleolae, and p. 281, affinities of *Christiania*). The arguments for the author's views are found above (pp. 9—13 and 37,195). In the description of the vascular system, Williams uses a different terminology, and material from many more groups than the author. Except for this the main difference between his opinion and that of Williams seem to be that the author attempts to follow the development of the ventral vascular system of the Orthacea back to more primitive stages than that of *Billingsella*.

Through comparison with modern forms Williams arrives to the conclusion that a periostracal pad united the valves, and acted as a ligament in many fossil brachiopods. The author arrived to the same conclusion by the study of the muscle impressions, and the growth-lines on the pseudodeltidium and the areas. The presence of a supra-apical foramen in connection with a pseudodeltidium might have something to do with this. The pseudodeltidium was generally found in connection with a strong periostracal pad, and in Strophomenids with a large functional pedicle, which increased in diameter as the animal growed, the pedicle foramen increased in diameter by resorption of shell tissue. This resorption (observed i. a. in *Leptaena rhomboidalis*) was not radial, but eccentric, moving the centre of the foramen further into the ventral valve. This was probably due to the presence of the periostracal pad, which made growth in the opposite direction impossible or at least difficult. In these species the adult pedicle foramen also include the apical part of the delthyrium, and from the adult specimens alone, it is impossible to conclude if the foramen originally was supra-apical or apical. It is therefore possible that the supra-apical foramen in some groups is a secondary feature formed by directed resorption away from the delthyrium because of the presence of a strong periostracal pad. This might explain the presence of the supraapical foramen in the Nisusids, and perhaps other groups.

Even if the author disagees with WILLIAMS in some anatomical and taxonomic details, he wholeheatedly subscribe to the conclusions given by him, both as regards the anatomical interpretation of the morphological features, and their taxonomic importance.

3) COOPER, G. A. 1956: Chazyan and related Brachiopods. Smithsonian Misc. Coll. vol. *147*, pp. 1—1245, 269 pls. Washington.

This monumental work on the Middle Ordovician brachiopods of North America has immensely increased our knowledge of the Ordovician faunas. Because of its excellent figures, clear diagnoses of genera and species, complete stratigraphic data, and well arranged indexes it is also handy and easy to use in spite of its size.

A large number of new genera are named, and some of the species described by the author belong to them. *Diambonia* (?) *leifi* and *Leptelloidea* (s.l.) *rosendahli* belong to *Bilobia*, and *Eoplectodonta* (?) *karina* to *Anisopleurella*. It is possible that *Strophomena* (*Gunnarella*) *beta* and *delta* belong to *Bellimurina* and that *Leptaena minuta* KIÆR and *Leptaena* sp. (cf. pl. 7 fig. 13) belong to *Cyphomena*.

The number of genera which are common to the Middle Ordovician of North America and the Oslo Region is rather high, they are: *Paleostrophomena*, *Ptychoglyptus*, *Eoplectodonta*, *Leptellina*, *Bilobia*, *Anisopleurella*, *Sowerbyella*, *Christiania*, *Chonetoidea*, *Leptaena*, *Oepikina*, *Strophomena*, *Rafinesquina*, and possibly *Bellimurina* and *Cyphomena*.

Some of the species described by COOPER might be identical with some in this paper, or at least very nearly related to them. They are: *Bilobia hemisphaerica* COOPER (p. 760, pl. 193 D) is very like *B. rosendahli*, *Leptaena ordovicica* COOPER (p. 820, pl. 228 B) is very like *L. strandi*. *Eoplectodonta* (?) *dubia* COOPER (p. 810, pl. 209 C) is quite like *E. acuminata*, and *Christiania platys* COOPER (p. 861, pl. 210 D, 215 B, G) is quite like *C. holtedahli*. Further studies might also show identical or nearly related species in *Sowerbyella* and *Leptellina*.

The resemblance between the Norwegian and the North American strophomenid faunas is striking, and when the rest of the brachiopods are described, the number of common genera and species will certainly increase.

It is difficult to try a correlation based on one animal group only, and the author will therefore only point out two remarkable features in the distribution of the strophomenids. The fauna in zone 4b*α* seem to correspond asthonishingly well to that found in the lower part of the Portersfield stage in the Appalachians, especially the Boutetort, Arline and Efna formations. The fauna found in the Coelosphaeridium beds in the Ringsaker district (and only here) seem to correspond to that found in the upper part of and just above the Wilderness stage, the Oranda, Rodman and Martinsburg formations.

Generally it is supposed that zone 4b*α* and the Coelosphaeridium beds are not very different in age (cf. STØRMER 1953, p. 113), and this problem has to be investigated.

The classification used by COOPER deviates sligthly from that used in this paper, especially in the higher units within the Plectambonitacea, but some of COOPERS new subfamilies have very brief diagnosis, and this classification has to be studied more in detail.

EXPLANATION TO PLATES

All photographs are unretouched. The specimens with preserved calcareous valves are marked *calc.* The casts are marked *cast*, and the artificial impressions, made of latex or plasteline are marked *impr.* If the casts are made by dissolving the valves in hydrochloric acid. *HCl* is added to *cast.*

If possible the name of the collector is given, according to the labels. The following abbreviations are used: *Hz*= professor A. Heintz, *Hm* = Dr. G. Henningsmoen, Sk = State Geologist S. Skjeseth, Sp = the author, St. = professor L. Størmer. These abbreviations are also used in STØRMER (1953, p. 40). Other abbreviations are: OH = professor O. Holtedahl, JK = professor J. Kiær, TS = Professor T. Strand.

PLATE 1.

Fig. 1. *Ptychoglyptus valdari.* sp. n. 66933. Ventral interior, impr. Railway section W. of Billingstad st., Asker district. zone 4b*α*. Coll. Sp. 1,3 5x.

Fig. 2. *Ptychoglyptus valdari* sp. n. 18853 Holotype. Dorsal interior, impr. Road section at Slependen, Asker district. zone 4b*α*, Coll. Hz. 1,45x

Fig. 3. *Ptychoglyptus valdari* sp. n. 56080. Exterior of dorsal valve, impr. Loc., Hor. and Coll. as fig. 2. 2,45x.

Fig. 4. *Grorudia* (?) *glabrata* sp. n. 66930, ventral interior, impr. Sentralinstituttet, Blindern, Oslo. Zone 4a*β*—4b*α* (transition) Coll. Sp. 2,6x.

Fig. 5. *Alwynella osloensis* sp. n. 66940 Holotype. Dorsal interior and exterior, impr. E. of Tåsen st., Oslo. zone 4a*β*. Coll. Sp. 4,1x

Fig. 6. *Alwynella ildjernensis* sp. n. 66928, Holotype, dorsal interior and exterior, impr. Northern side of Ildjernet, Nesodden, Oslo—Asker district. Zone $4a\alpha_4$. Coll. Sp. 3,8x.

Fig. 7. *Grorudia grorudi* sp. n. 66938, ventral interior, cast HCl. Vassholmen, near Snarøya, Bærum district, Zone 4a*β*. Coll. Sp. 3,3x.

Fig. 8. *Grorudia* (?) *glabrata* sp. n. 66929 Holotype. Dorsal interior, impr. Sentralinstituttet, Blindern, Oslo. Zone 4a*β*—4b*α* (transition) Coll. Sp. 2,1x.

Fig. 9. *Alwynella osloensis* sp. n. 69931, dorsal interior, impr. E. of Tåsen st. Oslo. Zone 4a*β*. Coll. Sp. 3,8x.

Fig. 10. *Grorudia grorudi* sp. n. 66939 Holotype. Dorsal interior, impr. E. of Tåsen st. Oslo. Zone 4a*β*. Coll. Sp. 4,0x.

Fig. 11. *Grorudia grorudi* sp. n. Dorsal interior, impr. Tørtberg, Oslo. Zone 4a*β*. Coll. H.-F. Grorud. 4,0x.

Fig. 12. *Grorudia* (?) *glabrata* sp. n. 66941, ventral interior, small specimen, cast. Sentralinstituttet, Blindern, Oslo. Zone 4a*β*—4b*α* (transition). Coll. Sp. 9,2x.

Fig. 13. *Paleostrophomena* (?) *majori* sp. n. 64790 Holotype, ventral interior, impr. Shore section between Gravestrand and Saltboden, Frierfjord, Langesund—Gjerpen district. Bryozoan beds (99—100 m up in the section). Coll. St and H. Major. 1,7x.

Fig. 14. *Alwynella osloensis* sp. n. 66934, ventral interior, impr. E. of Tåsen, Oslo. Zone 4a*β*, Coll. Sp. 2,7x.

Fig. 15. *Alwynella intermedia* sp. n. 66935 Holotype, fragmentary dorsal valve, calc. North-eastern side of Ildjernet, Nesodden, Oslo—Asker district. Zone 4a*β*—$4a\alpha_4$ (transition). Coll. Sp. 4,2x.

Fig. 16. *Alwynella intermedia* sp. n. 66937, exterior of ventral valve, calc. Loc. Hor. and Coll. as fig. 15. 5,6x.

Fig. 17. Indet Strophomenid, nr. 3 36819, exterior, calc. Railway section just N. of Hamar, Hamar—Nes district. Zone $4a\alpha_1$ (just above 3c) Coll. TS, 2.9x.

Fig. 18. *Grorudia* (?) *glabrata* sp. n. 66936, fragment with sculpture, calc. Sentralinstituttet, Blindern, Oslo. Zone 4a*β*—4b*α* (transition) Coll. Sp. 7,8x.

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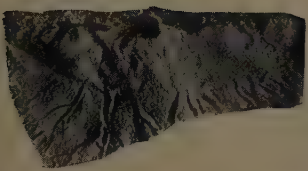

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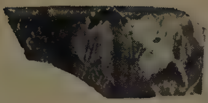

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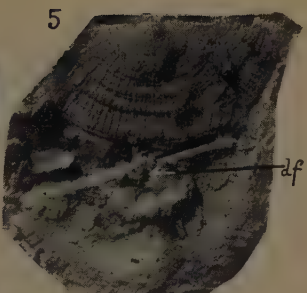

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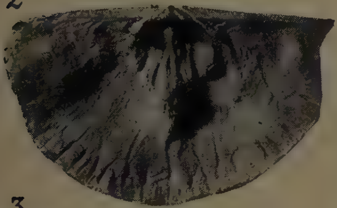

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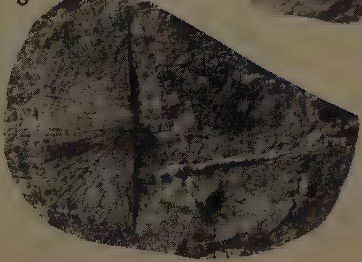

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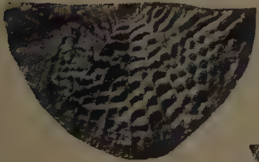

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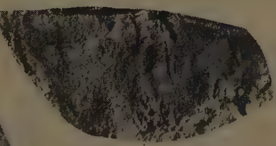

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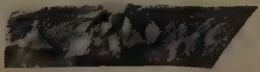

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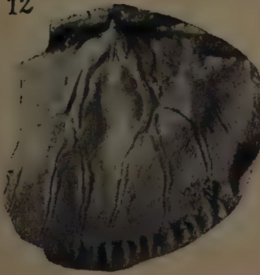

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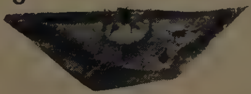

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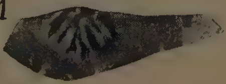

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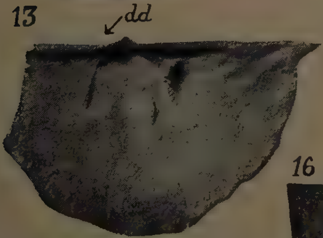

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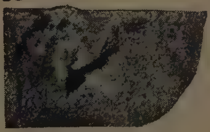

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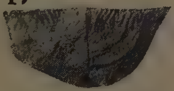

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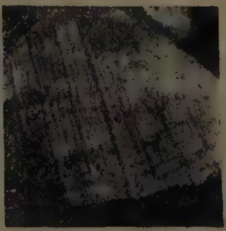

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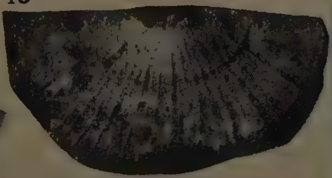

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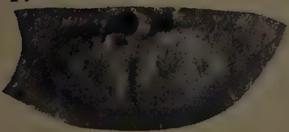

PLATE 2.

Figs. 1, 2. *Leangella hamari* sp. n. 37879, dorsal and ventral view of HOLOTYPE calc. Slightly etceded with dilute hydrochloric acid to show the interior. Cyclocrinus Shale, Furuberget, Hamar—Nes district. Coll. OH 1907. 4,5x.

Fig. 3. *Leangella hamari* sp. n. 66983 Dorsal interior, cast HCl Hor. Loc. and coll. as above .2,5x.

Figs. 4, 5. *Leptelloidea* (s. l.) *rosendahli* sp. n. 66984 HOLOTYPE Dorsal and ventral wiew of interior cast. Brummundal, Ringsaker district. Coll. H. Rosendahl. 3x.

Fig. 6. *Diambonia anatoli* sp. n. 66985 HOLOTYPE, dorsal interior, cast. Road section just N. of Halsen, Nesøya, Asker district, Zone 4b*α*. Coll. Sp. 3,6x.

Figs. 7, 8. *Diambonia anatoli* sp. n. 66986 and 66987, ventral interiors, casts, showing median septum (ms). Loc. Hor. and Coll. as above. 3,6x.

Figs. 9, 11. *Diambonia* (?) *leifi* sp. n. 64785, dorsal and ventral wiew of complete specimen, impr. 99—100 up in the section between Gravestrand and Skjelbukten, Langesund—Gjerpen District. Coll. H. Major & St. 5,3x.

Fig. 10. *Diambonia* (?) *leifi*, sp. n. 57536. Dorsal interior, cast. HOLOTYPE. Just N. of Stranda, Frierfjord, Langesund—Gjerpen district. Mastopora beds. Coll. St. 5,3x.

Fig. 12. *Chonetoidea gamma* sp. n. 66988 HOLOTYPE, dorsal interior, cast. Blakstad Road Junction, Asker district, zone 4b*γ*, coll. Sp. 4,5x.

Fig. 13. *Chonetoidea gamma* sp. n. 66989 dorsal interior, cast, showing badly defined branchial arcs, and some large spines outside them. Loc., Hor. and coll. as above. 4,5x.

Fig. 14. *Chonetoidea iduna* ÖPIK. 66966, dorsal interior, cast. Billingstad Asker district, zone 4 c*α*. Coll. Sp. 4,5x..

Figs. 15—16. *Sampo* (*Sampo*) *indentata* sp. n. 66990 and 66991. Dorsal interiors, impr. Railway section N. of Hvalstad st., Asker district, zone 4b*γ*, Coll. Sp. 3,1x.

Fig. 17. *Sampo* (*Leptellina*) *oepiki* (WHITTINGTON). 66993. ventral interior, cast. Coelosphaeridium beds, Ringsaker. Coll. Sk, 2,4x.

Fig. 18. *Sampo* (*Leptellina*) *oepiki* (WHITTINGTON), 66992. Dorsal interior, cast, S. end of Nakholmen, beside the large syenite dike. Oslo district. Zone 4b*α*, Coll. Sp. 5,3x.

Fig. 19. *Sampo* (*Leptellina*) *oepiki* (WHITTINGTON) 57733. Dorsal interior, impr. At 5. telephone pole S. of the curve S. of Ruden, Hadeland. Zone 4b*α*-*β*. Coll. TS. 2,2x.

Fig. 20. *Chonetoidea alpha* sp. n. 67027, HOLOTYPE, dorsal interior, cast. Above the second tunnel W of Billingstad st. Asker district. Zone 4b*α*, Coll. Sp. 6,2x.

Figs. 21—22. *Chonetoidea alpha* sp. n. 67028 and 67029. Ventral interiors showing ventral cavities (vc) Loc., Hor. and coll. as above. 6,2x.

PLATE 2

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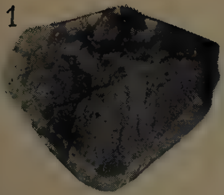

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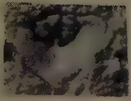

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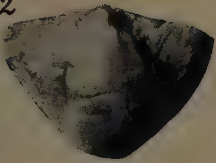

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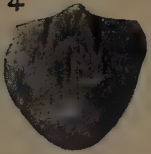

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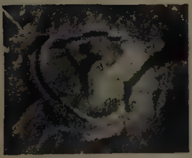

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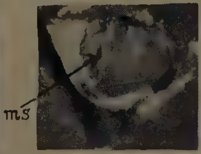

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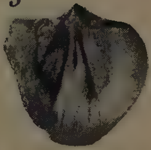

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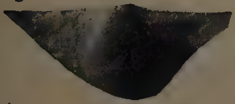

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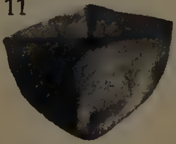

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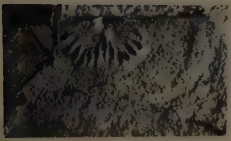

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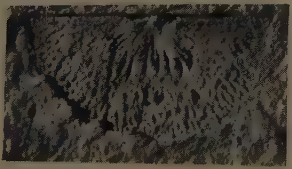

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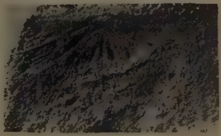

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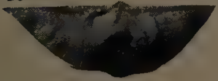

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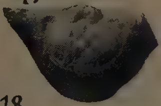

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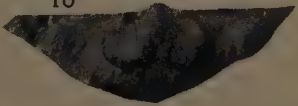

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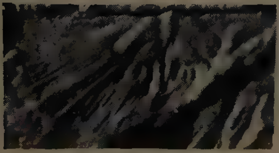

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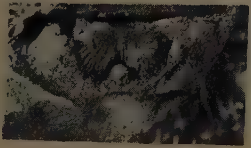

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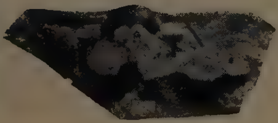

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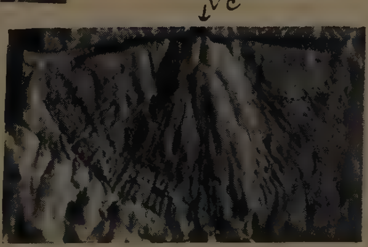

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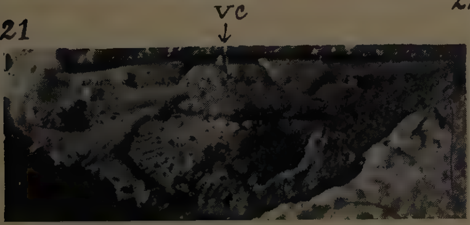

PLATE 3.

Fig. 1. *Sowerbyella sericea soudleyensis* Jones. L. 85, larval dorsal interior, impr. Bergsvika, Helgøya, Hamar—Nes district, Cyclocrinus beds. Coll. OH. Cf. Holtedahl 1916, pl. XIV, fig. 3. 12x.

Figs. 2—3. *Sowerbyella sericea soudleyensis* Jones, 66977 Ventral interior and exterior of larval valves, impr. Stavsberget, Helgøya, Hamar—Nes, district, Coll. JK 12x.

Fig. 4. *Sowerbyella sericea soudleyensis* Jones. L. 85, dorsal interior of an adult specimen. impr. Hor. Loc. and Coll. as in fig. 1. 2,8x.

Fig. 5. *Eoplectodonta karina* sp. n. 66978 Holotype. Dorsal interior, calc. SE. end of Nakholmen, Oslo district. Zone 4bα, Coll. Sp. 5,5x.

Fig. 6. *Eoplectodonta acuminata* (Holtedahl) 66979, Ventral interior, cast, showing denticulation (d.). Southern end of Nakholmen, Oslo district. Zone 4bα, Coll. Sp. 5,5x.

Fig. 7. *Eoplectodonta acuminata* (Holtedahl) 66980. Dorsal interior, impr. Loc., Hor. and Coll. as fig. 6. 2,9x.

Fig. 8. *Eoplectodonta acuminata* (Holtedahl) 66981. Showing corrugations on the exterior of the dorsal valve, and the areas. Loc., Hor. and Coll. as fig. 6. 7x.

Fig. 9. *Eoplectodonta acuminata* (Holtedahl) 66982. Ventral interior, impr. showing ciliar groves (Cg). Vesleseter, Sjåstad district. Zone 4bα. Coll. St. 3,5x.

Fig. 10. *Eoplectodonta acuminata* (Holtedahl) 19025, Dorsal interior, impr. Royal Palace, Oslo. Zone 4bα. Old collection. 3,5x.

Fig. 11. *Eoplectodonta acuminata* (Holtedahl) 5279, Lectotype. Exterior of dorsal valve and areas. Loc., Hor. and coll. as fig. 10. 3,5x.

Fig. 12. *Eoplectodonta acuminata* (Holtedahl) 5278, Ventral interior, impr. Loc., Hor. and Coll. as in fig. 10. 3,5x.

PLATE 3

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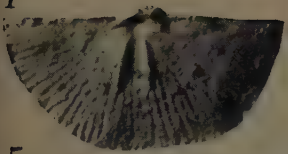

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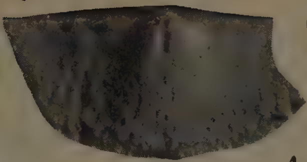

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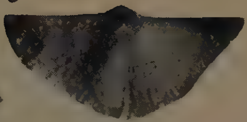

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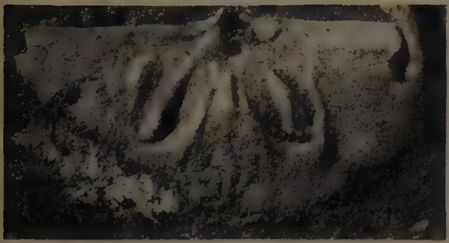

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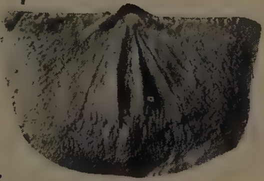

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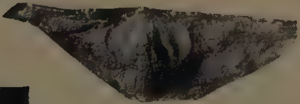

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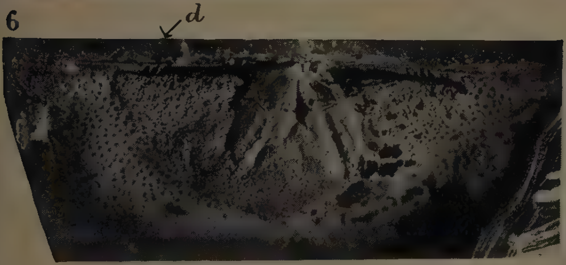

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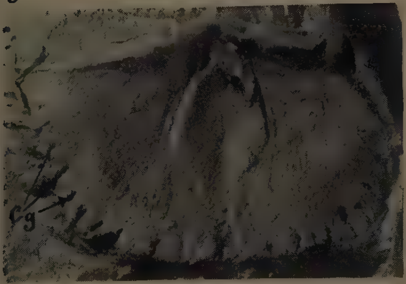

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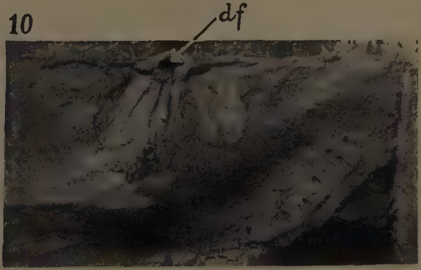

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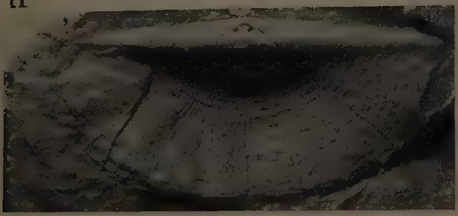

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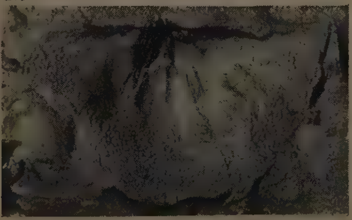

PLATE 4.

Fig. 1. *Sowerbyella sericea hadelandica* subsp. n. 67138 Holotype. Ventral exterior calc. From the lower Cyclocrinus beds in a section between Jonsrud and Stensrud in the northern part of Hadeland. Coll. TS. 2,8x.

Figs. 2—3. *Eoplectodonta* (?) *rhombica* (McCoy) 64371. Two different wievs of a ventral interior, cast HCl, showing the denticulated hinge-line. From zone 4bδ at Vestern—Grindvoll, Hadeland district. Coll. St. & Hm. 1,35x.

Fig. 4. *Leptestia* (?) *jukesi* (Dav.) 8682. Ventral interior, cast, from the Bryozoan zone at Skjælbugten, Langesund—Gjerpen district. Coll. W. C. Brøgger 1881. 1,35x.

Fig. 5. *Leptelloidea* (s. l.) 66634. Fragmentary dorsal interior (impr.) from the transitional beds between zone 4aα_4 and 4*aβ* at Muggerudkleiva, Eiker—Sandsvær district. Coll. St. Hz. Hm. Sp. 1,9x.

Fig. 6. *Sampo* (*Leptellina*) *oepiki* (Whittington) 57733, Ventral interior cast, showing the vascular system. From zone 4ba—β at 5. telephone pole S. of the curve S. of Ruden, Hadeland district. Coll. TS. 5,5x.

Fig. 7. *Sowerbyella sericea hadelandica* subsp. n. 67134. Dorsal interior, cast, from the lower Cyclocrinus beds in a section between Jonsrud and Stensrud in the northern part of Hadeland. Coll. TS, 2,8x.

Fig. 8. *Sampo* (*Sampo*) *indentata* sp. n. 67135. Holotype. Ventral interior, cast, HCl, showing vascular system. From zone 4bγ in a railway section W. of Billingstad, Asker district. Coll. Sp. 5,5x.

Fig. 9. *Eoplectodonta* (?) *percedens* (Holtedahl). 67137. Ventral interior, cast HCl, showing the denticulated hinge-line. From zone 4bβ at Blakstad brygge, Asker district. Coll. Sp. 3,7x.

Fig. 10. *Leptelloidea* (*Benignites*?) *heintzi* sp. n. 66651. Holotype. Ventral interior, cast, from zone 4aα_3 at Ravaldsjøelven, Eiker—Sandsvær district, Coll. St, Hz, Hm, Sp. 2,9x.

Fig. 11. *Leptelloidea* (*Benignites*?) *heintzi* sp. n. 66651. Smaller ventral interior from the same piece of rock as the holotype. 2,8x.

PLATE 4

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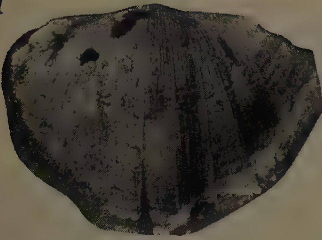

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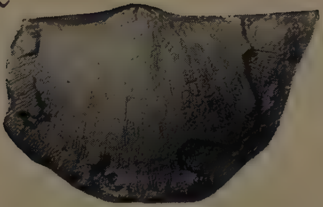

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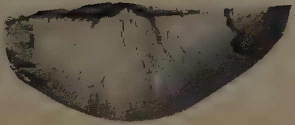

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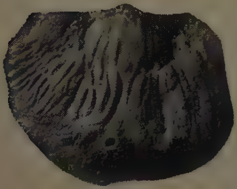

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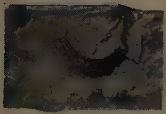

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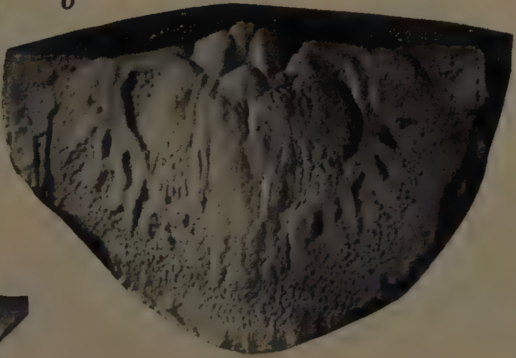

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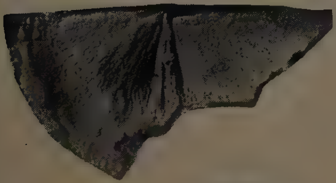

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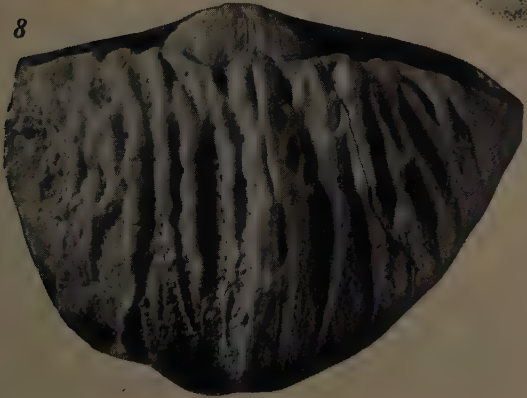

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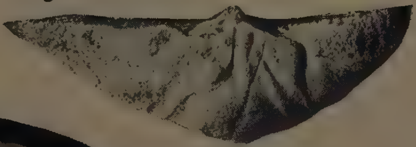

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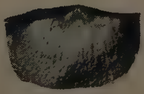

PLATE 5.

Figs. 1—9. *Christiania holtedahli* sp. n., a series of larval and young valves from zone 4b*α* at Blakstad Road Junction, Asker district. *1,6* (66942, 66947) Dorsal exteriors, impr. 3,3x, *2,5* (66943, 66946) Dorsal interiors in which the cardinal processes are not differentiated from the socket plates. 3,3x. *3* (66944) ventral interior, 1,8x. *4*. (66945) Dorsal interior with cardinal processes well differentiated. 1,8x. *9* (66950) Dorsal interior of young adult specimen, 1,8x. *7* (66948) Dorsal exterior with growth-lines, cast. 5x. *8* (66949) Smallest dorsal interior 5x. cast. Coll. Sp.

Figs. 10—11. *Christiania holtedahli* sp. n. L144, HOLOTYPE. Two different aspects of the same ventral interior, showing vascular markings and intervascular septa. Bratterud, Ringerike, zone 4b*α*—*β*. cast. The specimen was also figured by HOLTEDAHL 1916, pl. XVI, fig. 7. 1,8x. Coll. JK.

Fig. 12. *Christiania elongata* sp. n. 66967 HOLOTYPE Interior of both valves, showing the dorsal side, cast. Sentralinstituttet, Blindern, Oslo district. Zone 4a*β*—4b*α*. 1,8x. Coll. Sp.

Fig. 13. *Christiania* cf. *oblonga* (PANDER) 66968, Specimen with partly exfoliaated ventral valve, showing the dorsal interior. Calc. S. of Vassholmen, Snarøya, Oslo district, zone 4a*β*. 1,5x. Coll. Sp.

Fig. 14. *Christiania oblonga* (PANDER), 60368 Fragmentary ventral interior, cast. Muggerudkleiva, Eiker—Sandsvær district. Zone $4a\alpha_{1\text{-}2}$. 1,8x. Coll. St.

Fig. 15. *Christiania holtedahli* sp. n. 66969. Dorsal interior, calc. of a large specimen. Arnestadtangen, Asker district. Zone 4b*α* Coll. Sp. 2,4x.

Fig. 16. *Christiania holtedahli* sp. n. 66970. Ventral interior with distinct pseudopuncta and intervascular septa. cast. Brattberg, Ringsaker, Coelosphaeridium beds. 1,25x. Coll. Sk.

Figs. 17—22. *Christiania oblonga* (PANDER), 66971—66976, a series of dorsal interiors, calc. from Popowka near Leningrad. Probably from zone C1, or slightly lower. *17—18*. Two valves in different views, 6x. *19—22*. Four different types of cardinal processes found in this species. 13x. Those shown in figs. *19, 22* are the common ones.

PLATE 5

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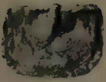

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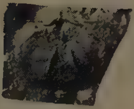

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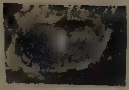

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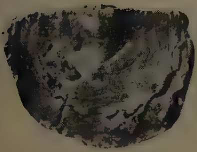

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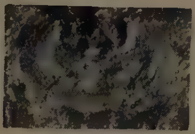

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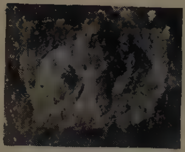

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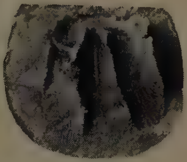

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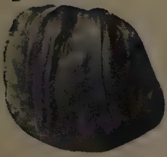

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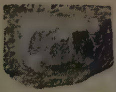

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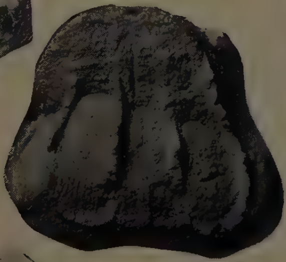

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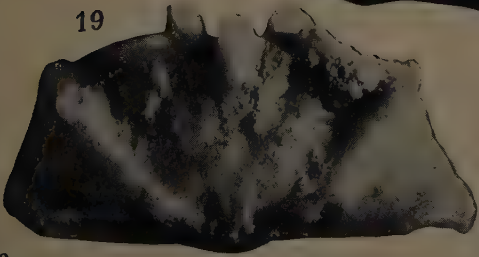

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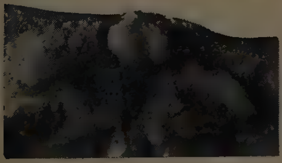

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PLATE 6.

Figs. 1—2. *Sowerbyella ringsakerensis* sp. n. 66952 and 66951. Dorsal interiors of young specimens, impr. Bratberg, Ringsaker, Coelosphaeridium zone. 2,7x. Coll. Sk.

Fig. 3. *Sowerbyella ringsakerensis* sp. n. 66951 HOLOTYPE. Dorsal interior, impr. Loc. Hor. and Coll. as figs. 1—2. 2,7x.

Fig. 4. *Sowerbyella ringsakerensis* sp. n. 66953. Ventral interior of highly gerontic specimens, cast. Hor., Loc. and Coll. as fig. 1—2. 4x.

Fig. 5. *Sowerbyella sericea askerensis* subsp. n. 66954 HOLOTYPE. Ventral interior, cast. Railway section N. of Hvalstad st., Asker district. Zone 4bγ. Coll. Sp. 4x.

Fig. 6. *Sowerbyella sericea soudleyensis* JONES, 66977. Detail of ventral interior, impr., showing muscle impressions and ventral cavities (vc). Stavsberget Helgøya, Hamar—Nes district, Cyclocrinus Beds. Coll. JK. 11,5x.

Fig. 7. *Eoplectodonta* (?) *percedens* (HOLTEDAHL), L132, LECTOTYPE. Exterior of ventral valve. calc. Bratterud, Ringerike. Zone 4b (*α*—*β*). Coll. JK. impr. 1,85x.

Figs. 8—9. *Christiania* cf. *holtedahli* sp. n. 66955. Ventral interior of pathological (?) specimen. Gomnes—Rud, Ringerike, zone 4bα. Coll. JK. 2,8x.

Fig. 10. *Christiania holtedahli* sp. n. 66956. Dorsal interior (impr.) of large specimen. Vesleseter, Sjåstad district. Zone 4bα. Coll. St. 2,3x.

Figs. 11—12. *Sampo* (*Leptellina*) *elevata* sp. n. 7513, HOLOTYPE. Ventral interior, cast. Gomnes—Rud. Ringerike. Zone 4bα. Coll. JK. 2,8x.

Fig. 13. *Mjoesina* cf. *mjoesensis* (HOLTEDAHL), 66957. Ventral interior, impr. of a specimen which resemble the typical form. Bratberg, Ringsaker, Coelosphaeridium Beds. Coll. Sk. 1,5x.

Fig. 14. *Christiania oblonga* (PANDER), 60368. Exterior and interior of dorsal valves, impr. Muggerudkleiva, Sandsvær—Eiker district. Zone 4aα_{1-2}. Coll. St. 1,8x.

Fig. 15. *Leptaena strandi* sp. n. 57837, HOLOTYPE, Ventral interior, cast. Road section between Jonsrud and Stensrud, Hadeland. Zone 4bα—*β*. Coll. TS, 2,5x.

PLATE 6

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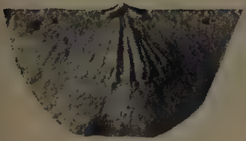

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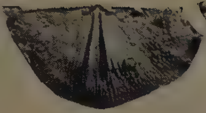

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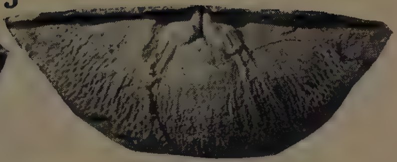

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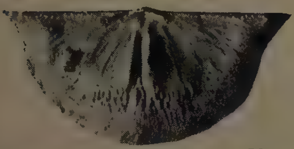

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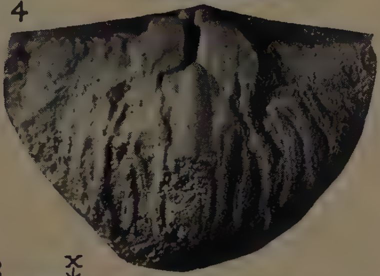

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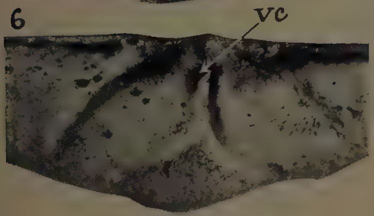

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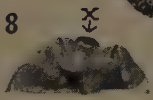

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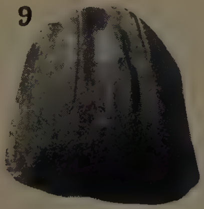

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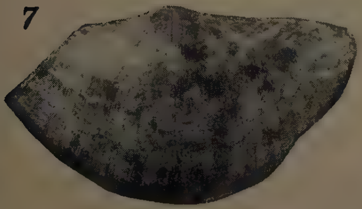

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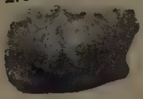

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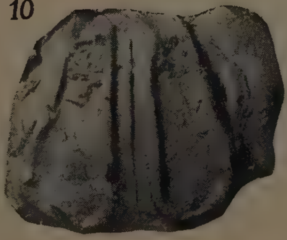

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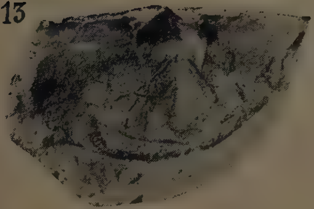

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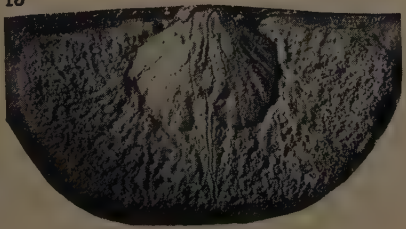

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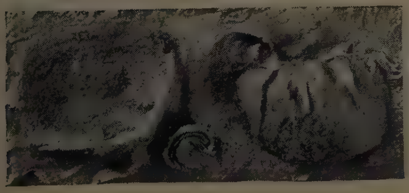

PLATE 7.

Figs. 1—2. *Leptaena rugosa* DALMAN. Br. 10441 and Br. 10420. Ventral interiors, cast. Ålleberg, Vestergötland, Sweden. Dalmanitina-zone. Coll. unknown. 1,1x.

Fig. 3. *Leptaena emarginata* (BARRANDE) Br. 32644. Ventral interior showing pedicle foramen (pf) and outline of muscle impressions (dark). calc. Visby, Gotland, Sweden. Silurian, probably upper Llandovery or lower Wenlock. Coll. unknown. 1,1x.

Fig. 4. *Leptaena rugosa* DALMAN, Br. 10435 LECTOTYPE. Dorsal exterior, cast. Fårdalaberg, Vestergötland, Sweden. Dalmanitina-zone. Coll. Dalman 1827. 1,1x.

Fig. 5. *Kjerulfina foliovalve* sp. n. 66958. Dorsal interior, impr. showing the pedicle (?) groove in a young specimen (pg). Railway section N. of Hvalstad st. Asker district. Zone 4bγ. Coll. Sp. 3,2x.

Figs. 6, 8. *Leptaena minuta* KIÆR. 66959. Dorsal and ventral interiors, cast. Tønnerudodden, Hadeland. Sphaeronid Limestone. Coll. JK. 2,5x.

Fig. 7. *Leptaena minuta* KIÆR. 34716. LECTOTYPE. Exterior of dorsal valve, calc. Tønnerudodden, Hadeland. Sphaeronid Limestone. Coll. JK. 2,5x.

Fig. 9. *Leptaena* sp. Br. 32218. Fragmentary dorsal interior (calc.) showing the details of the muscle impressions. Eksta Djupvik, Gotland, Sweden. Wenlock. Coll. unknown, 1,6x.

Figs. 10—12. *Kiaeromena* cf. *juvenilis* (ÖPIK) 66960 and 66961. Dorsal and ventral interior and ventral exterior of the same specimen (cast HCl). Bratberg, Ringsaker, Coelosphaeridium Beds. Coll. Hm. 1x.

Fig. 13. *Leptaena* sp. 66962. Dorsal interior, impr. Bratberg, Ringsaker, lowest part of Coelosphaeridium beds. Coll. Sk. 1,75x.

Fig. 14. *Kiaeromena kjerulfi* (HOLTEDAHL) 66963, Small, complete specimen, calc. Ildjernet, Nesodden. Oslo district. Zone 4bβ. Coll. Sp. 1x.

Fig. 15. *Leptaena depressa* (SOW.) Br. 32215. Ventral interior (calc.) showing structure of teeth (d) and ventral muscle impressions. Eksta Djupvik, Gotland Sweden. Coll. unknown. 4x.

Fig. 16. *Kiaeromena kjerulfi* (HOLTEDAHL) 66964. Fragment showing healed fracture (z) in the valve (cast). Lindøya, Oslo district. Zone 4bβ. Coll. Sp. 6x.

Fig. 17. *Kiaeromena juvenilis* (ÖPIK) 66965. Dorsal interior (calc.) showing chilidium (ch) with slight fold. Kukruse, Esthonia. Zone C2α. Coll. A. ÖPIK 5x.

The specimens with Br-numbers, belong to the Swedish State Museum of Natural History, Dept. of Paleozoology, Stockholm, Sweden.

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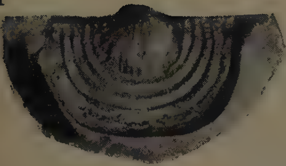

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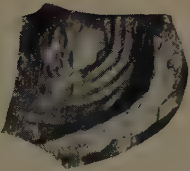

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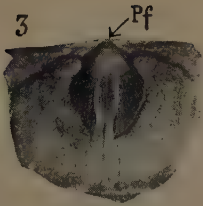

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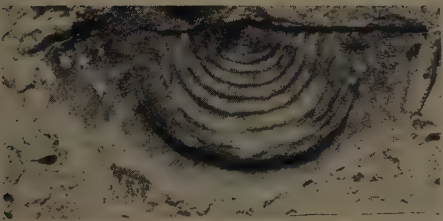

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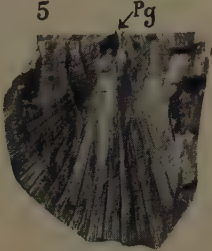

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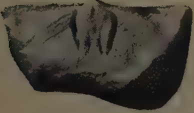

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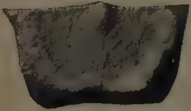

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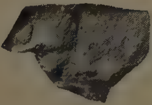

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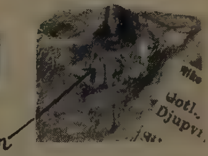

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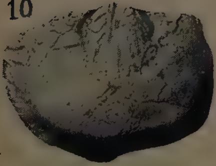

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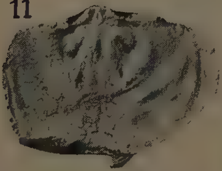

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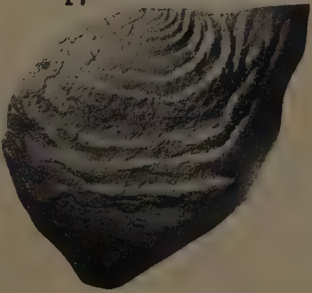

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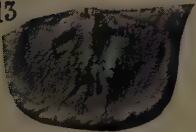

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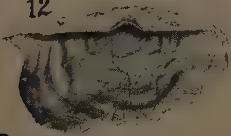

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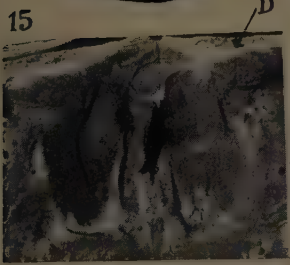

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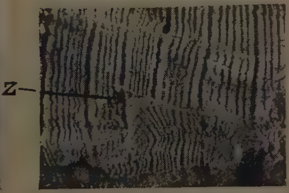

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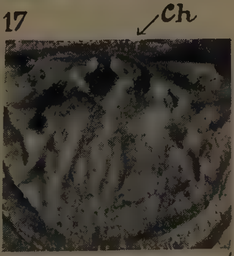

PLATE 8.

Fig. 1. *Rafinesquina* (*Hedstroemina*) aff. *robusta* (BANCROFT), 66998, Fragmentary dorsal interior (impr.). Brummundal, Ringsaker district. Coelosphaeridium zone. 1,35x. Coll. H. Rosendahl.

Figs. 2—4. *Rafinesquina* (*Hedstroemina*) aff. *robusta* (BANCROFT). 66999. Ventral (2) and dorsal interiors (impr.) Loc., Hor. and Coll. as in fig. 1. 2x.

Fig. 5. *Rafinesquina* (*Hedstroemina*) cf. *robusta* (BANCROFT) 66995, Ventral interior, impr. Bruflaten, Veldre (boulder). Coelosphaeridium zone. Coll. Sp. 1,3x.

Fig. 6. *Mjoesina mjoesensis* (HOLTEDAHL) 67001, Ventral interior, cast. Furuberget, Hamar—Nes district. Cyclocrinus-beds. Coll. OH. 2,4x.

Fig. 7. *Mjoesina* cf. *mjoesensis* (HOLTEDAHL) 67002, Ventral interior, cast. Brattberg, Ringsaker district. Coelosphaeridium-beds. Coll. Sk. 1,8x.

Fig. 8. *Rafinesquina* (*Rafinesquina*) sp. 67003, Ventral interior, cast. Brattberg, Ringsaker district. Coelosphaeridium-beds. Coll. Sk. 1,3x.

Fig. 9. *Rafinesquina* (*Hedstroemina*) *ungula*, 7835, Exterior of ventral valve, calc. Vestbråten, Ringerike, Zone 4bγ, Coll. JK. 1x.

Fig. 10. *Rafinesquina* (*Hedstroemina*) *ungula* sp. n. 7834 HOLOTYPE. Ventral interior, cast. Vestbråten, Ringerike. Zone 4bγ. Coll. JK. 1x.

Fig. 11. *Rafinesquina* (*Hedstroemina*) *ungula* sp. n. 67000 Dorsal interior, cast. Vestbråten, Ringerike. Zone 4bγ. Coll. JK. 1x.

Fig. 12. *Mjoesina gregaria* sp. n. 66994, Dorsal exterior, cast. Sund, Einavatn, Toten. Coelosphaeridium Beds. Coll. N. Heintz & Sk. 1x.

Fig. 13. *Mjoesina gregaria* sp. n. 66996, HOLOTYPE. Ventral interior, cast. Sund, Einavatn, Toten. Coelosphaeridium Beds. Coll. N. Heintz & Sk. 1x.

Fig. 14. *Rafinesquina* (*Hedstroemina*) *holtedahli* sp. n. 66997, HOLOTYPE. Ventral interior. Røyselandet, Ringerike. Zone 4bα-β. Coll. JK. 1,8x.

PLATE 8

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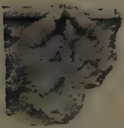

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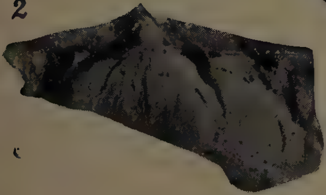

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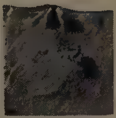

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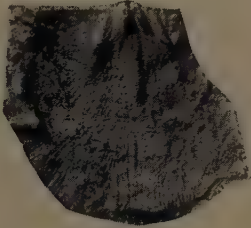

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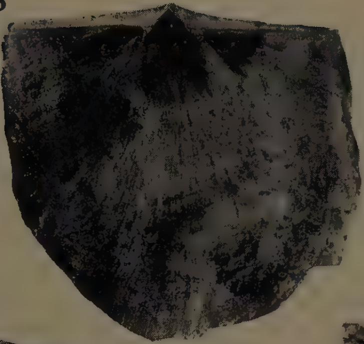

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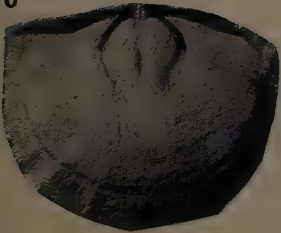

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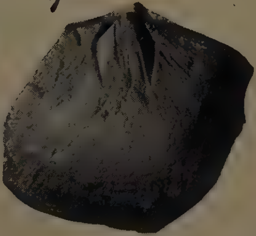

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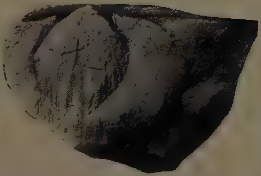

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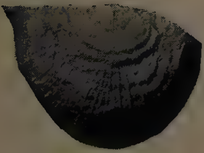

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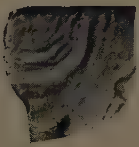

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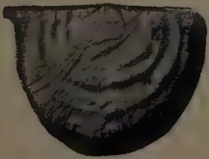

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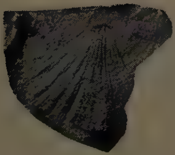

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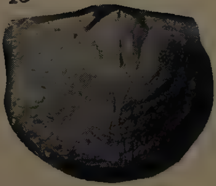

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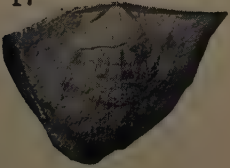

PLATE 9.

Fig. 1. *Kjerulfina foliovalve* sp. n. 67004, HOLOTYPE. Dorsal interior, impr. Railway section N. of Hvalstad St., Asker district. Zone 4bγ. Coll. Sp. 1,25x.

Figs. 2—3. *Kjerulfine foliovalve* sp. n. 67005 and 67006. Dorsal interiors, impr. Loc., Hor. and Coll. as in fig. 1. 1,25x.

Fig. 4. *Kjerulfina limbata* sp. n. 67011, HOLOTYPE. Ventral interior, cast. Vestbråten, Ringerike. Zone 4bγ. Coll. St. 1,25x.

Fig. 5. *Kjerulfina foliovalve* sp. n. 67007. Dorsal exterior of larval valve. cast. Loc., Hor. and Coll. as in fig. 1. 8,8x.

Fig. 6. *Kjerulfina orta* (ÖPIK), 67144. Ventral interior. calc. Kukruse, Esthonia. Zone C2. Coll. A. Öpik. 1,25x.

Fig. 7. Indet Strophomenid nr. 1. 67010. Fragmentary dorsal interior, impr. Lauervann, Eiker—Sandsvær district. Coll. Hz. 1,6x.

Fig. 8. *Kjerulfina foliovalve* sp. n. 67009. Dorsal interior and exterior, impr. Loc., Hor. and Coll. as in fig. 1. 1,25x.

Fig. 9. *Kjerulfina limbata* sp. n. 67012. Dorsal interior, impr. Loc., Hor. and Coll. as in fig. 4. 1,35x.

Fig. 10. *Kjerulfina limbata* sp. n. 67008. Somewhat atypical ventral interior, impr. Loc., Hor. and Coll. as in fig. 4. 1,35x.

Fig. 11. *Strophomena* sp. 9330. Dorsal exterior, calc. Frognøya, Ringerike. Zone 4bδ_2, zone of *Tretaspis kiaeri*. Coll. JK. 1,7x.

Fig. 12. *Strophomena* (*Gunnarella*) *beta* sp. n. 55427. HOLOTYPE. Complete specimen with partly exfoliated ventral valve, calc. Bratterud, Ringerike. Zone 4bβ. Coll. JK. 0,85x.

Fig. 13. *Oslomena* (?) *papillio* sp. n. 38184. Exterior of ventral valve, impr. Road between Sund and Eksberget, Toten. Cyclocrinus-beds ?. Coll. JK. 2,2x.

Fig. 14. *Oslomena* (?) *papilio* sp. n. 38184. HOLOTYPE. Dorsal interior, impr. Loc., Hor. and Coll. as in fig. 13. 2,2x.

Fig. 15. *Oslomena* (?) *papilio* sp. n. 38138. Ventral interior, impr. Loc., Hor. and coll. as in fig. 13. 2,2x.

Fig. 16. *Strophomena* (*Gunnarella*) cf. *rigida* (BARRANDE) 9330. Dorsal (?) exteriors calc. Loc., Hor. and Coll. as in fig. 11. 1,7x.

PLATE 9

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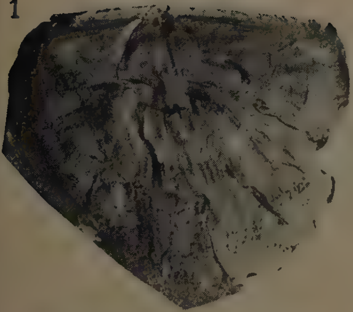

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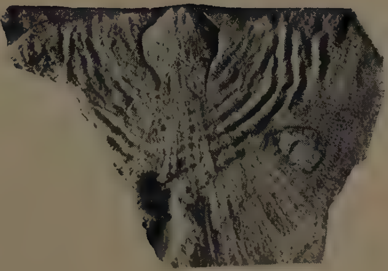

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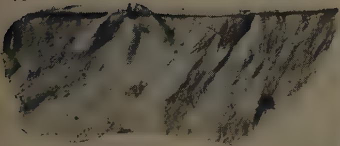

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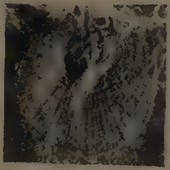

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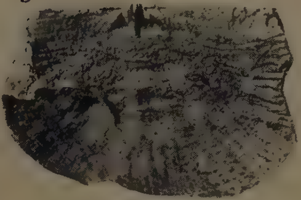

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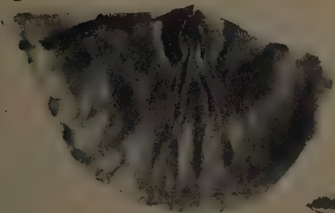

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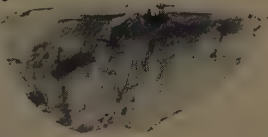

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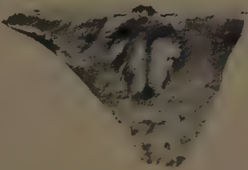

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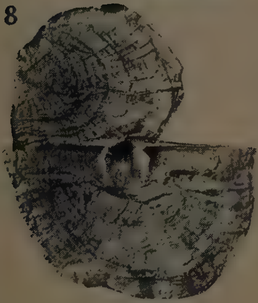

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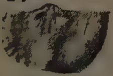

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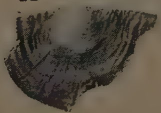

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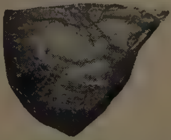

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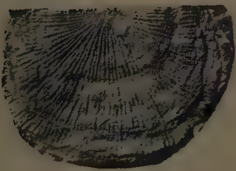

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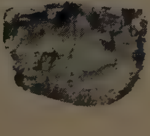

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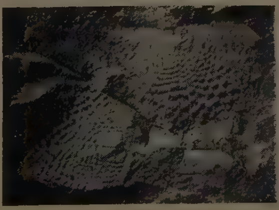

PLATE 10.

Figs. 1—2. *Kiaeromena kjerulfi* (Holtedahl) 67014. Dorsal and ventral interior, cast. Lindøya, Oslo district. Zone 4bβ. Coll. T. Kjerulf. 1,5x.

Fig. 3. *Kiaeromena kjerulfi* (Holtedahl), 66964. Ventral interior, cast. Loc. and Hor. as in fig. 1—2. Coll. Sp. 0,85x.

Fig. 4. *Leptaena strandi* sp. n. 67018. Ventral interior, cast. Gomnes—Rud, Ringerike district. 2,8x. Zone 4bα, upper part. Coll. JK.

Fig. 5. *Leptaena strandi* sp. n. 67019. Holotype. Ventral interior, cast. Railway section W. of Billingstad st. Asker district. Zone 4bγ. Coll. Sp. 2,2x.

Fig. 6. *Leptaena veldrensis* sp. n. 67017. Holotype. Ventral interior, cast. Brattberg, Ringerike district. Coelosphaeridium beds. Coll. Sk. 3×.

Figs. 7—8. *Leptaena veldrensis* sp. n. 67015. Dorsal interiors, impr. Loc., Hor. and Coll. as in fig. 6. 1,75x.

Fig. 9. *Leptaena ennessbe* sp. n. 67016. Holotype. Ventral interior, cast. Railway section W. of Billingstad st. Asker district. Zone 4bα. Coll. Sp. 2,7x.

Fig. 10. *Leptaena* (?) *indigena* sp. n. 37455. Dorsal interior, impr. Fangberget, Ringsaker district. Coelosphaeridium-beds. Coll. Braastad. 1,1x.

Fig. 11. *Leptaena* (?) *indigena* sp. n. 67013. Holotype. Ventral interior, impr. Brattberg, Ringsaker district. Coelosphaeridium-beds. Coll. Hm. 1,1x.

PLATE 10

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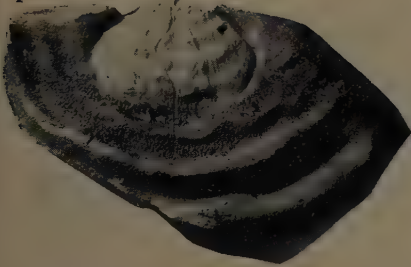

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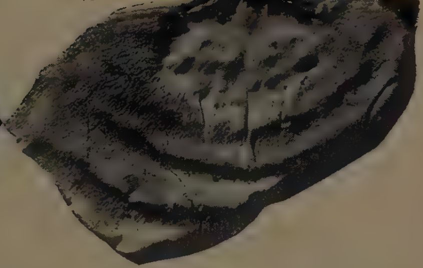

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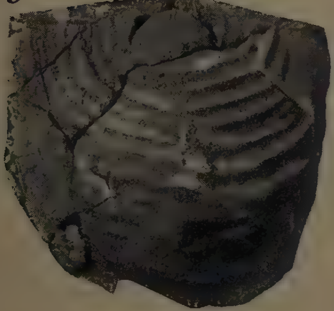

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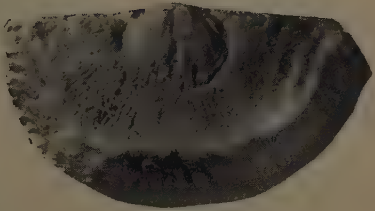

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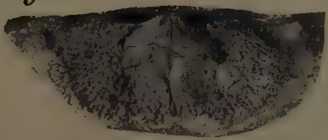

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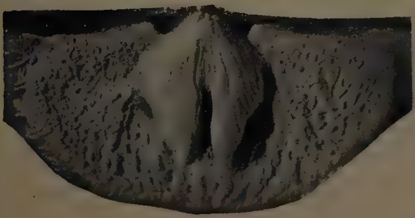

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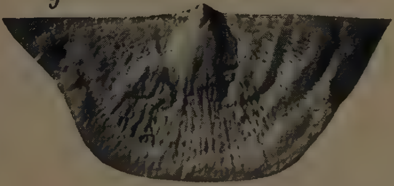

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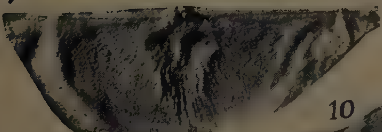

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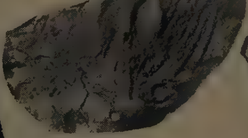

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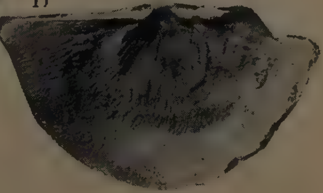

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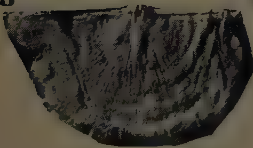

PLATE 11.

Fig. 1. *Strophomena norvegica* sp. n. 7117, HOLOTYPE. Dorsal interior, impr. W. side of Røysetangen, Ringerike district. Zone 4bα. Coll. J.K. 1,8x.

Fig. 2—3. *Strophomena norvegica* sp. n. 7117 and 67020. Ventral interiors, and exterior of areas impr. Loc., Hor. and Coll. as in fig. 1. 1,8x.

Fig. 4. *Kjerulfina lata* sp. n. 21965. Exterior of ventral valve, impr. Furuberget, Hamar—Nes district. Coelosphaeridium-beds. Coll. OH. 2x.

Fig. 5. *Strophomena* (*Gunnarella* ?) *alpha* sp. n. 67021. HOLOTYPE. Ventral interior, impr. Railway section W. of Billingstad st. Asker district. Zone 4bα. Coll. Sp. 1,5x.

Fig. 6. *Strophomena* (*Gunnarella* ?) *alpha* sp. n. 67023. Ventral exterior, impr. Loc., Hor. and Coll. as in fig. 5, 1,5x.

Fig. 7. *Kjerulfina lata* sp. n. 21967. HOLOTYPE. Ventral interior, impr. Loc., Hor. and Coll. as in fig. 4. 2x.

Fig. 8. *Kjerulfina* sp. 67024. Ventral interior, impr. 99—100 m in the section between Gravestrand and Skjælbugten, Frierfjord, Langesund—Gjerpen district. Mastopora zone. Coll. Major & St. 1,5x.

Fig. 9. *Strophomena hirsuta* ? sp. n. 38040. Dorsal interior, impr. possibly belonging to this species, or a young specimen of *S. steinari*. Fangberget, Ringsaker district. Coelosphaeridium-beds. Coll. OH. 1,1x.

Fig. 10. *Strophomena hirsuta* sp. n. 67022, Ventral interior, cast. Fangberget, Ringsaker district. Coelosphaeridium-beds. Coll. OH. 0,95x.

Fig. 11. *Strophomena steinari* sp. n. 67026. HOLOTYPE. Ventral interior, impr. Brattberg, Ringsaker district. Coelosphaeridium-beds. Coll. Sk. 0,8x.

Fig. 12. *Strophomena steinari* sp. n. 67025. Dorsal interior, impr. Loc. and Hor. as in fig. 11, Coll. Hm. 0.8x.

PLATE 11

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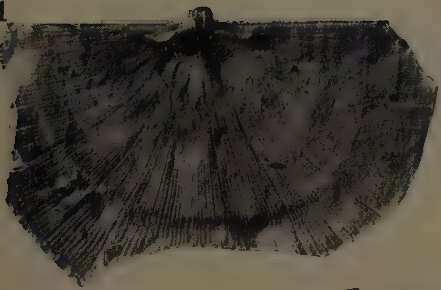

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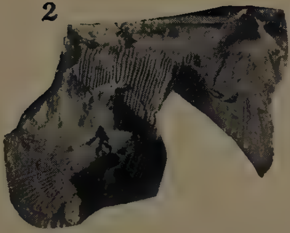

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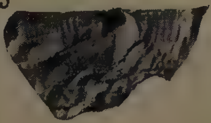

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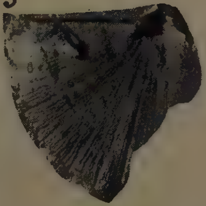

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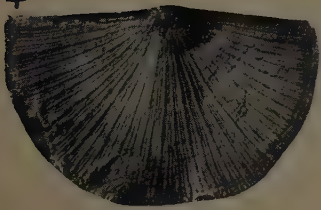

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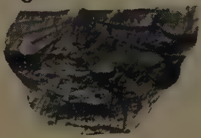

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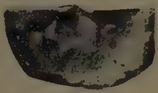

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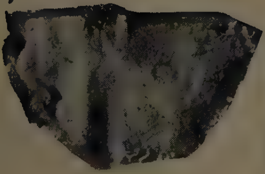

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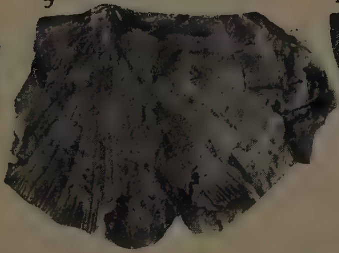

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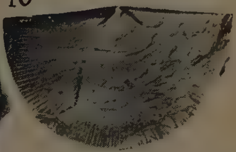

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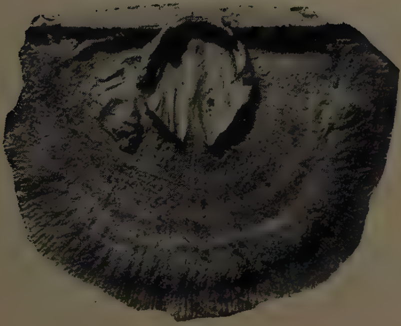

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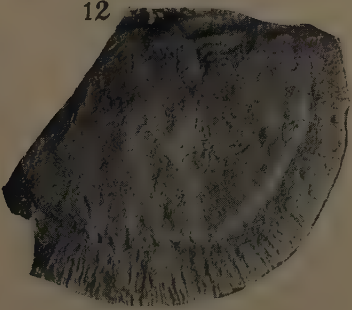

PLATE 12

Fig. 1. *Strophomena* (*Gunnarella*) *delta* sp. n. 67145. HOLOTYPE. Dorsal interior, calc. from zone 4bδ at the SW-ern end of Borøya, Bærum, Oslo—Asker district. Coll. Sp. 1,9x.

Fig. 2. *Stropheodonta* (*Eostropheodonta*) *williamsi* sp. n. 67140. Ventral interior, impr. from the Coelosphaeridium beds at Brattberg, Ringsaker district. Coll. Sk. 1x.

Fig. 3. *Strophoedonta* (*Eostropheodonta*) *williamsi* sp. n. 36164, HOLOTYPE. Dorsal interior, impr. of a gerontic specimen from the Cyclocrinus beds at Furuberget, Hamar—Nes district. Coll. JK. 1,1x.

Figs. 4—5. *Stropheodonta* (*Eostropheodonta*) *williamsi* sp. n. 37380, two different views of a dorsal interior, impr. From the Coelosphaeridium beds at Fangberget, Ringsaker district. Coll. OH. 2x.

Fig. 6. *Stropheodonta* (*Eostropheodonta*) *helgoeyensis* sp. n. 38647, HOLOTYPE. Dorsal interior, impr. From the upper part of the Mjøsa Limestone at Bergvika, Helgøya, Hamar—Nes district. Coll. exc. 2,5x.

Fig. 7. *Strophonella* sp. Br. 35731. The area of a ventral valve, calc. showing the denticules (*d*) and denticules partly covered by growth of the area (*dg*). From the Mulde Marl (upper Wenlock) at Tegelbruket, Frøyel, Gotland, Sweden. 1,5x.

Fig. 8. *Strophomena neglecta* (JAMES) 67141. Area of ventral valve, calc., showing denticulated teeth (*d*). From the Richmondian (Maynesville) of Blanchester, Ohio, U.S.A. 1,5x.

Fig. 9. *Oepikina dorsata media* (ÖPIK) 64756. Ventral interior, impr. from the bryozoan zone at Gravestranden, Frierfjord, Langesund—Gjerpen district. Coll. St. & H. Major. 1,9x.

Fig. 10. *Oepikina dorsata media* (ÖPIK) 67143. Dorsal interior, impr. showing a specimen resembling *Oslomena* in the development of the branchial septa. From the Bryozoan zone at Gravestranden, Frierfjord, Langesund—Gjerpen district. Coll. W. C. Brøgger. 1,9x.

Fig. 11. *Rafinesquina* or *Oepikina* sp. 67136. Fragmentary ventral interior, impr. from 150 m S. of Vesleseter, Sjåstad district. Coll. St. & Hm. 1,9x.

Figs. 12—13. *Oslomena osloensis* sp. n. Dorsal and ventral wiews of a complete specimen cast HCl. From zone 4bα, railway section W. of Billingstad, Asker district. Coll. Sp. 2,3x.

Fig. 14. *Rafinesquina* (*Kjaerina*) *lepta* sp. n. 67133. HOLOTYPE. Dorsal interior, calc. from the lower part of zone 4bδ at Rauskjær, Oslo—Asker district. Coll. Sp. 3,4x.

Fig. 15. *Oslomena osloensis* sp. n. 67142. HOLOTYPE. Ventral interior, cast HCl, from zone 4bα at Arnestad, S. Vollen i Asker, Oslo—Asker district. Coll. Sp. 3,7x.

Fig. 16. *Oslomena osloensis* sp. n. 67139. Ventral area, cast HCl, showing structure of pseudodeltidium (*Pd*) and the cardinal processes (*dent*). From zone 4bα at Arnestad, S. of Vollen i Asker, Oslo—Asker district. Coll. Sp. 10x.

PLATE 12

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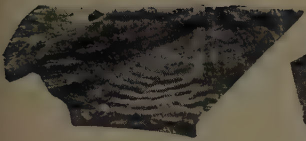

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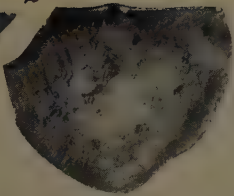

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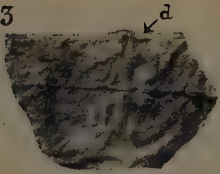

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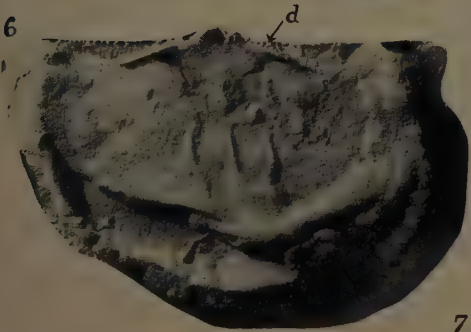

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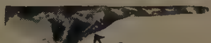

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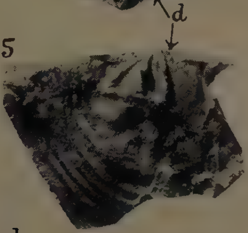

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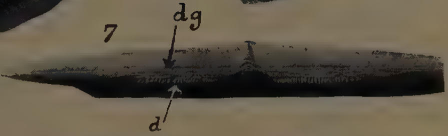

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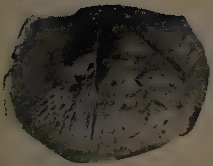

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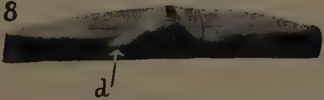

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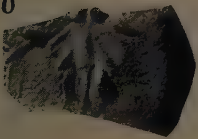

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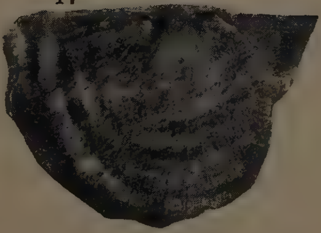

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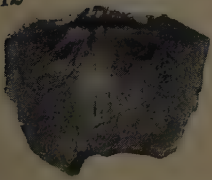

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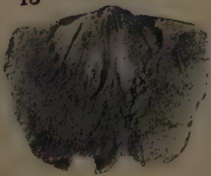

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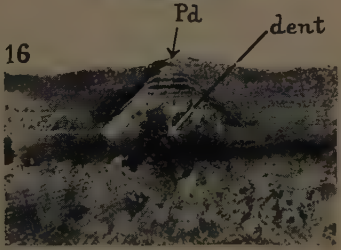

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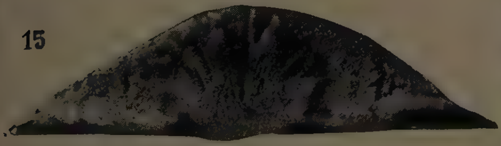

PLATE 13

All figures are about 50x. except fig. 2, which is about 25x.

Fig. 1. *Leptaena depressa* (SOW.) dry peel of the dorsal valve of a specimen from the Mulde Marl, Frøyel, Gotland, Sweden, showing pseudopuncta.

Fig. 2. *Oslomena osloensis* sp. n. Dry peel of ventral valve of specimen from zone 4bα at Billingstad, Oslo—Asker district, showing small puncta.

Fig. 3. *Leptaena depressa* (SOW.) Thin section, showing the pseudopuncta in the dorsal valve of a specimen from the same horizon and locality as that in fig. 1.

Fig. 4. *Inversella* sp. Dry peel showing pseudopuncta in a specimen from zone B3 in the Leningrad district.

Fig. 5. *Sampo* (*Sampo*) *indentata* sp. n. Thin section showing pseudopuncta from the ventral valve of a specimen from zone 4bγ, north of Hvalstad st. Asker district.

Figs. 6—7. *Ptychoglyptus valdari* sp. n. Thin sections showing puncta and nonpunctate radial rib (*R*) in a specimen from zone 4bα at Billingstad, Asker district.

Fig. 8. *Strophomena neglecta* (JAMES) thin section showing pseudopuncta partly obscured by recrystallisiation. Richmondian, Ohio, U.S.A.

PLATE 13

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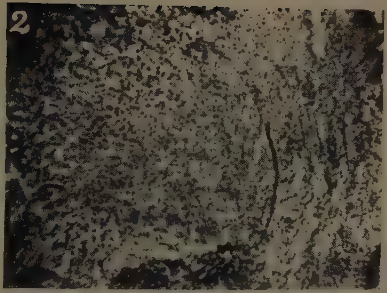

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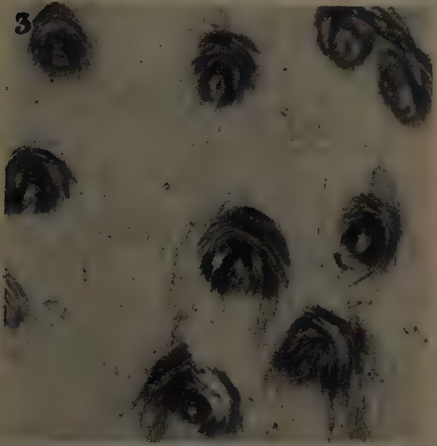

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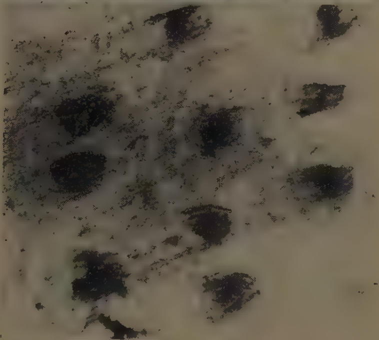

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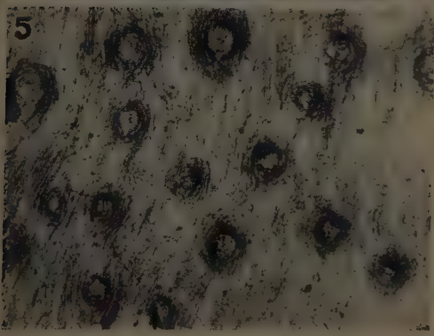

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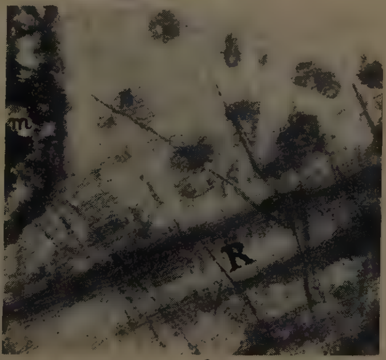

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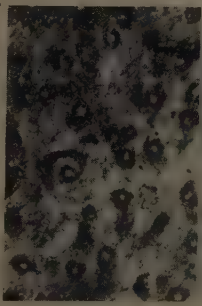

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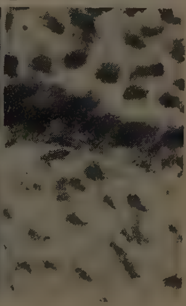


PLATE 14

Photomicrographs showing the structure of the shell.

Figs. 3—4 are about 50x, fig. 5 is about 40x, and the rest are about 17x.

Fig. 1. *Strophomena planumbona* Hall (Ordovician, U.S.A.). Section just behind the cardinal processes, showing the supporting tissue of the latter (*Cb*), the socket plates (*Sp*), the teeth (*D*) the semidenticles of the teeth (*de*) and the irregular, pseudopunctate tissue in the sockets (*Sf*). Dry peel. Cf. textfig. 3E.

Fig. 2. *Kiaeromena kjerulfi* (Holtedahl) from zone 4bβ at Langåra, Oslo—Asker district. Dry peel, showing the teeth, cf. textfig. 40A.

Fig. 3. *Leptaena depressa* (Sow.) from Frøyel, Gotland, Sweden. Thin section showing a pseudopunctum with open aperture, and filled with a yellowish substance differing from the clear calcite in the rest of the specimen (cf. p. 10).

Fig. 4. *Leptaena depressa* (Sow.) from Frøyel, Gotland, Sweden. Dry peel showing the structure of a tooth, with the irregular, semidenticulated border towards the dorsal valve (*DV*).

Fig. 5. *Leptaena depressa* (Sow.) from Frøyel, Gotland, Sweden. Thin section showing a pseudopunctum in longitudinal section.

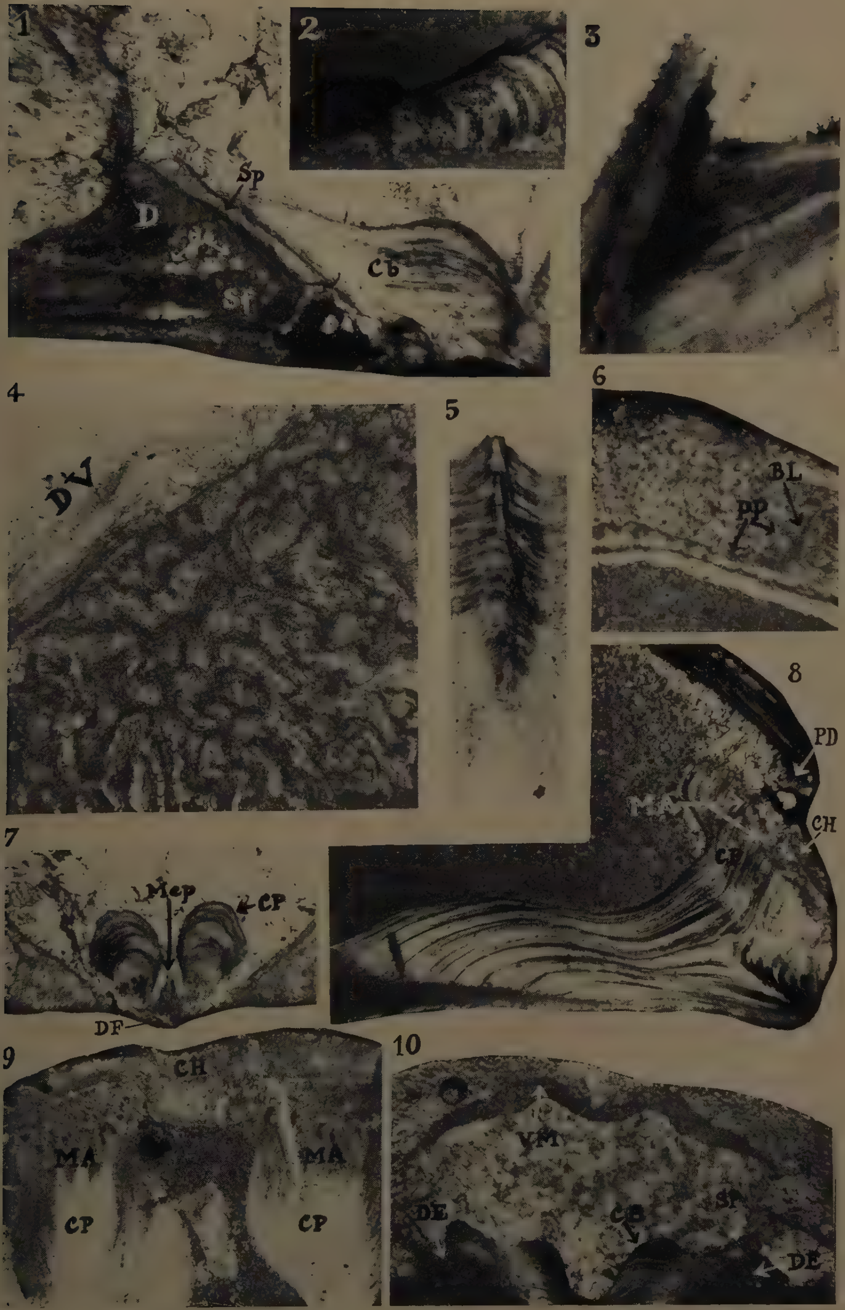
Fig. 6. *Sampo* (*Sampo*) *indentata* sp. n. from zone 4bγ, Billingstad, Asker district, showing the structure of the branchial lamellae (BL), being formed by horizontal pseudopunctae (*PP*).

Fig. 7. *Oepikina dorsata* (Bekker), from zone C2, Kukruse, Esthonia, showing the cardinal processes (*CP*), the rudimentary median cardinal process (*Mcp*) and the dorsal foramen (*DF*) cf. textfig. 2C.

Fig. 8. *Leptaena depressa* (Sow.) from Frøyel, Gotland, Sweden, showing a longitudinal section through the deltidium and notothyrium. *CP* = Cardinal processes, *MA* = Muscle impressions, *CH* = Chilidium, *PD* = Pseudodeltidium.

Fig. 9. *Kiaeromena kjerulfi* (Holtedahl) from zone 4bβ at Langåra, Oslo—Asker district, showing the thick chilidium with median fold (*CH*) cardinal processes (*CP*) with characteristic muscle attachments (*MA*). Cf. textfig. 40D.

Fig. 10. *Oepikina dorsata* (Bekker) from zone C2, Kukruse, Esthonia, showing semidenticulated teeth (*DE*), socket plates (*SP*), bases of the cardinal processes (*CB*) and the tissue coating the ventral muscle impressions (*VM*). Cf. textfig. 2E.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THE MIDDLE ORDOVICIAN OF THE OSLO REGION, NORWAY

9. Brachiopods of the family Porambonitidae

BY

NILS SPJELDNÆS

(Palaeontological Institute, University of Oslo, Oslo 47, Norway).

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Abstract. Three species of Porambonitids are described from the Middle Ordovician of the Oslo Region, Norway. One of them, *Porambonites* (*Porambonites*) *kjerulfi* is new. The nomenclature, taxonomy and evolution of the family are discussed. The new species (*P.* (*P.*) *kjerulfi*) is related to the Lower Ordovician representatives of the family, and similar species are also found in other parts of Western Europe during the Middle Ordovician. The two other species, which both belong to the subgenus *Isorhynchus* KING, are Baltic ones.

Introduction.

The Norwegian Middle Ordovician material of Porambonitids is rather small. Altogether, there are only three well defined species, none of which are very common. Only a few specimens show the sculpture, and the internal structures is found in a number of casts, most of which are artificial. In order to examine the interior of the older, Lower Ordovician species, a serial section was made of a specimen of *P. reticulata* PANDER.

This paper is a part of a larger project, and the author is deeply indebted to Professor L. Størmer for his inspiring leadership of the team-work. I also wish to thank Mrs. A. C. Brenna, who has revised the manuscript, Miss B. Mauritz who has made the photographs, and Miss I. Lowzow, who has made the drawings.

The Family Porambonitidae.

The family Porambonitidae has been placed in different groups by different authors, and as it is a well defined group, the material from the Middle Ordovician of the Oslo Region is described here in a special paper.

Soon after the genus *Porambonites* had been established by PANDER (1830) the systematics of the group were discussed by a number of authors, a discussion which has continued ever since. For the opinions of the older authors, I can refer to TEICHERT (1930) and SCHUCHERT & COOPER (1932).

At present some authors (KOZLOWSKI 1929, ÖPIK 1930) regard the Porambonitidae as being Pentamerids, which, according to KOZLOWSKI (l. c.), belong in the Telotremata. SCHUCHERT & COOPER (1932) among others believe them to be aberant Orthids, and COOPER (1956) refer them to the Syntrophioidea.

There are at present two genera and one subgenus in the family Porambonitidae. The little known genus *Noetlingia* HALL & CLARKE (1896) has *Spirifer tscheffkini* VERNEUIL (1840) as the type, and only species. In the original description (PANDER 1830), *Porambonites* itself contained a large number of closely related species. They were united into larger specific units by later authors (v. BUCH and VERNEUIL). One of these larger units, *P. aequirostris* (SCHLOTHEIM 1820) was made the type species by DAVIDSON (1851—55). This was not in accordance with the rules of nomenclature as SCHLOTHEIM's species was not included in the original description of the genus. Another reason why this species should not have been chosen was that it was also the type species of *Isorhynchus* KING 1850. Later DALL (1877) selected *P. intermedia* PANDER (1830) as the type species, as did also HALL & CLARKE (1896). This was a most unfortunate choice as the species *intermedia* is crudely figure, and it is obviously indeterminable.

Realizing this TEICHERT (1930), selected *P. reticulata* PANDER (1830) as the type species. SCHUCHERT & COOPER (1932) also used this species as the type of the genus. This procedure might be convenient, but it is not in accodance with the rules of nomenclature. If *reticulata* is to be accepted as the type species, it is necessary to apply to the ICZN for the surpression of the selection of *intermedia*.

If the rules of zoological nomenclature should be followed rigidly in this case, the generic name *Porambonites* would have to be abandoned as the type species is not recognizible, and the name *Isorhynchus* KING should be used instead.

It is doubtful whether *P. reticulata* is suitable as the type species at all. The species is not well known, the interiors have not been studied before now, and the figures of *Noetlingia tscheffkini* (VERNEUIL 1840, pl. 2, fig. 1a-g) show a wide variation in outline, which might overlap with that of *P. reticulata* (ib. pl. 2, fig. 2a-f and PANDER 1830, pl. 14, fig. 2a-d). The internal structures are also similar, as far as they are known (HALL & CLARKE 1896, figs. 155—169 and this paper fig. 1). From the present studies, it seems possible that a gradual. transition exists between *Noetlingia* and *Porambonites*, and that *P. reticulata* is one of the intermediate species. If *Noetlingia* should be accepted as a valid genus, it therefore seems unadvisable to select *P. reticulata* as the type species of *Porambonites*. Other species, such as *P. intercedens* PANDER (1830) have a much more central place in the genus, as it is defined now.

The typical features in the evolution of the Porambonitids, are the reduction of the cardinal process, the traces of which is found even in the youngest species of *Isorhynchus* that have been studied, and the shortening of the straight hinge-line, which is very long in *Noetlingia*, shorter, but still prominent in *Porambonites* s. s., and absent, or nearly so in *Isorhynchus*.

In order to study the internal structure of *P. reticulata*, the author made a rough serial section through a specimen. The dry peel method was used (cf. SPJELDNÆS 1957). The sections show (text-fig. 1 *CH*) that an «orthoid» cardinal process was present. The validity of the genus *Noetlingia* may therefore be doubted, if it is still to be used, it must be as a subgenus. The diagnostic feature of the subgenus is the very long, straight hinge-line. (VERNEUIL's speci-

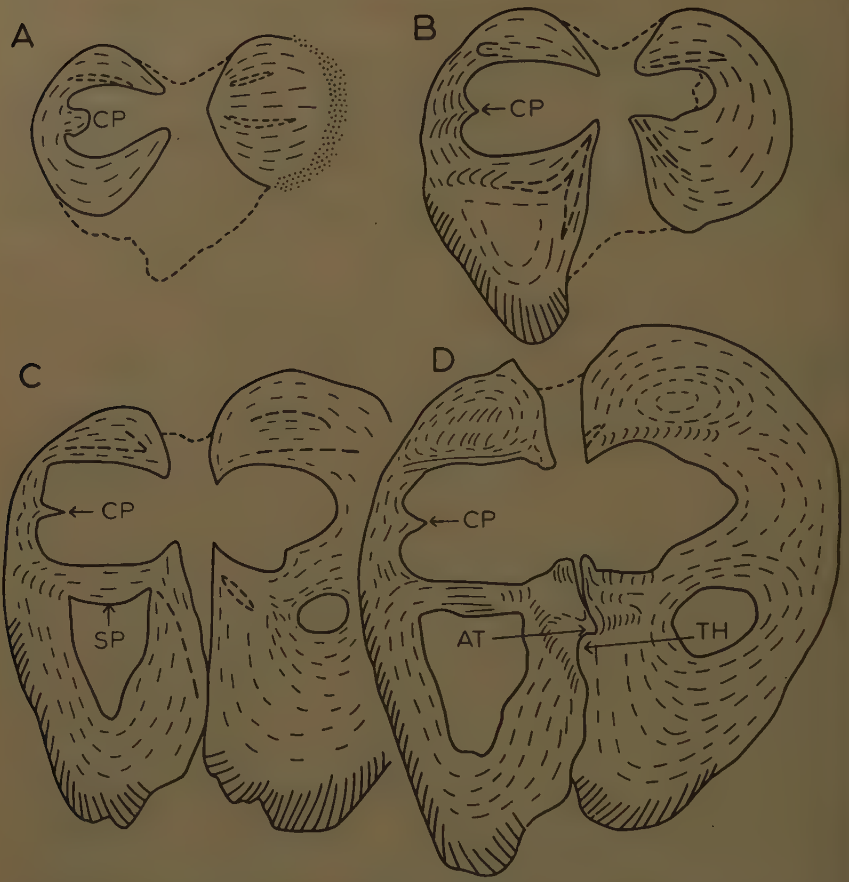

Fig. 1. A serial section (sligthly oblique) through the apical part of the valves of *Porambonites* (*Porambonites*) *reticulata* PANDER, from the Lower Ordovician at Popovka, near Leningrad. Abbreviations: AT = Accessory teeth, CP = Cardinal process, SP = Septum, TH = Teeth. About 5 x.

men on pl. 2, fig. 1a is taken as the type of *Spirifer tscheffkini*, that figured on pl. 2, fig. 2c-g is more like *P. reticulata*).

As mentioned above, all Porambonitids seen by the author have a cardinal process. It is strongly developed in the Lower Ordovician species. In the latter ones it is observed as a small median ridge between the socket plates (cf. SCHUCHERT & COOPER 1932, pl. 14 fig. 21). As there is no such structure in the ventral valve and as the gradual reduction to this ridge from an unmistakable cardinal process can be followed through several stages, it is taken for granted that this ridge represents the cardinal process.

The vascular system is found in several specimens (pl. 1, figs. 9—10), and has been figured by many authors (i. a. Sharpe 1853, Vinassa de Regny 1927, Schuchert & Cooper 1932 and several others). Except for minor differences the vascular system is similar in all observed specimens. In both the dorsal and the ventral valve, a large number of branches fork off from a main vessel running parallel to the septal plates. This polypalmate vascular system (see Spjeldnæs 1957, textfig. 10 M—N) may be an adaption of the ordinary orthoid vascular system, but it has a remarkable resemblance to the vascular system of the Clitambonitids. The arrangement of the vascular branches in relation to the spondylium is similar in both groups.

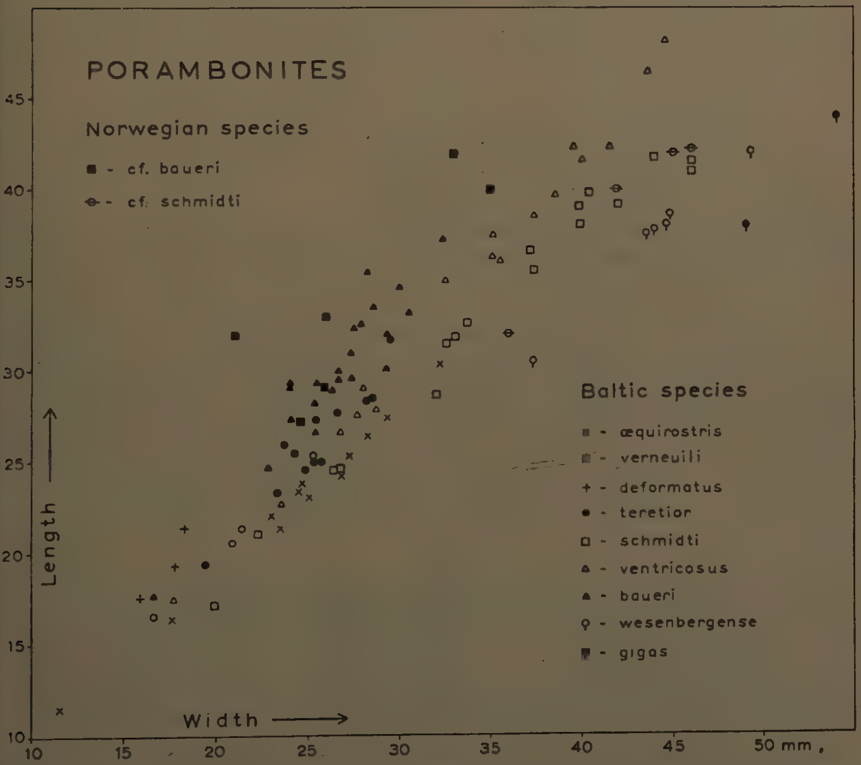

Fig. 2. Diagram showing the Length/Width ratio of some Baltic and Norwegian Porambonites species. Data about the Baltic ones from Teichert (1930).

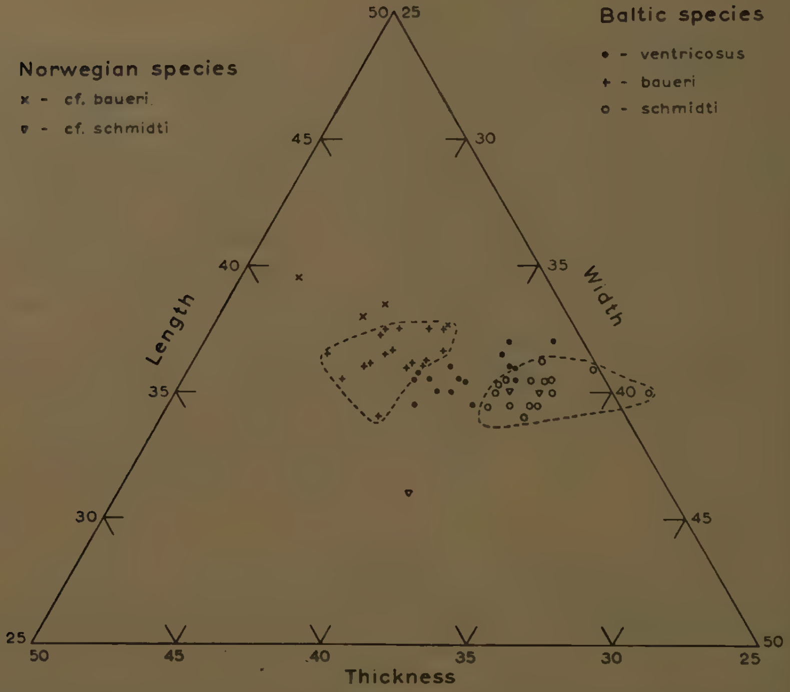

Fig. 3. Diagram showing the variability of some Baltic species of Porambonites (from TEICHERT 1930) supplied with data on Norwegian specimens.

Because of the small and poorly preserved material at the author's disposal, it is impossible to give any new arguments for the relationship of the Porambonitids. It seems to be a very conservative stock, which has features in common with several orthoid groups, including the Clitambonitids. Some species in the latter group show a «Porambonitid» stage in the development of their spondylium (cf. ÖPIK 1934, textfig. 1a).

Most species of the Porambonitidae need a redescription. It is very difficult to discriminate the species. Earlier authors mainly relied upon the length/width ratio, and the outline. These features are highly variable in most other brachiopod groups, and they can therefore only be used with the greatest care in the Porambonitidae. From the descriptions given by TEICHERT (1930) it appear that the species show an amazingly low variability. His biometrical data have been used as a basis for making two diagrams in this paper (textfigs. 2—3).

They show that some species can be distinguished by the measurements only. It must be remembered, however, that it is not known if all the specimens in the sample are measured, or if it is an «ontogenetic series». Neither is there any information on the purity of the samples. The Norwegian material show a much higher variability than that studied by TEICHERT (1930). The lower taxonomic units in the family Porambonitidae therefore need a revision, which must be done on the rich and well preserved Baltic material.

At present, the author recognizes only one genus in the Porambonitidae, *Porambonites*, PANDER 1830 with the illegal type species *P. reticulata* PANDER 1830. *Isorhynchus* KING 1850, type species *Terebratulites aequirostris* SCHLOTHEIM 1820 is accepted as a subgenus for the species with subtrigonal to subpentagonal outline, and very short straight hinge-line. *Noetlingia* HALL & CLARKE 1896 is provisionally accepted as a subgenus, but the relationship of *N. tscheffkini* to *P. reticulata* have to be studied in more detail.

Porambonites (*Porambonites*) *kjerulfi* sp. n.

Pl. 1, figs. 1—4, 9.

Diagnosis: A large species for the subgenus. Sculpture moderately coarse. Length/width ratio about 0,92—1,00. The thickness of the specimens is relatively small. The hingeline is long, and almost straight (at least 55—60% of the total width).

Type data: The holotype is PMO 67 040, a complete specimen from zone 4bβ at the southern end of Ildjernet, eastern side of the inner part of the Oslo Fjord.

Material: 1 dorsal interior, and fragments of several others. 4 complete specimens, and determinable fragments of at least 11 others.

Description: Outline almost circular, length/width ratio 0,92—1,00 (holotype 0.93). The specimens are unusually thin for the genus, the holotype, which is the thickest specimen measured has a width/thickness ratio of 1,63, most of the others are about 1,80. In other Middle Ordovician species, especially of the subgenus *Isorhynchus*, this ratio rarely exceeds 1,40 in adult specimens. Hinge-line wide and straight, at least 55—60% of the total width, and in many cases still longer. The sculpture is observed only in a few specimens, among them the holotype. It is relatively fine for the subgenus, but considerably coarser than in most species of *Isorhynchus*.

The dimensions and proportions of some well preserved specimens are as follows:

Specimen	Zone	District	Length	Width	Thickness	Hinge line	Length/width	Width/thickness
67 040 (holot.)	4bβ	Oslo–A.	37	40	27	24	0,93	1,63
34 427	Cycl.	Toten	28+	48	31	31	—	1,85
7 043	4bα–β	Ringerike	40	41	19+	28	0,97	≈2

The interior shows few differences from the other species of the genus. The teeth are remarkably strong, and accessory teeth are present in the dorsal valve. The dorsal interior shows relatively thin and low branchiophore plates even in adult specimens. They are also placed more closely together than in *Isorhynchus*. The ventral interior is not known in detail.

Remarks: *P.* (*P.*) *kjerulfi* belongs to the *intercedens* group of species with a long, straight hinge-line, relatively thin specimens and fine sculpture for the subgenus. It differ from *P.* (*P.*) *intercedens* as to size, and in being thinner. The hinge-line is also slightly longer in *kjerulfi*. *P. filosa* McCoy (1846) seem sto have a shorter hinge-line, and is thicker. *P.* (*P.*) *ribeiroi* Sharpe (1853) has a shorter hinge-line, but the same proportions of the shell, and may be closely related to *P.* (*P.*) *kjerulfi*. The figured specimens (Sharpe 1853, pl. 8 figs. 7a, c) are smaller than the specimens of *kjerulfi*, but the slight development of the interior indicates that they are young specimens. *P. magnus* (Menehegini) may also be a related species, judging from the figures given by Vinassa de Regny (1927, pl. 4, figs. 12—15). The differences between *kjerulfi* and the species belonging to the subgenus *Isorhynchus* are mentioned above.

Distribution: *P.* (*P.*) *kjerulfi* is one of the typical fossils in zone 4bβ in the Oslo—Asker district. Occasionally some small specimens also occur in the uppermost part of zone 4bα. Outside the Oslo—Asker district, it is found in two localities only, Røysetangen, Ringerike (a few specimens from zone 4bα-β) and one specimens from Tangen near Gjøvik, Toten district, in the Cyclocrinus beds.

Porambonites (*Isorhynchus*) *schmidti* NOETLING 1883.

Pl. 1 figs. 7—8, 10

1883 *Porambonites schmidti* sp. n. — NOETLING, pp. 356—362, pl. 15.
1921 *Porambonites schmidti* NOETLING — BEKKER, pl. 4, figs. 3—4.
1930 *Porambonites schmidti* NOETLING — TEICHERT, pp. 197—198, pl. 12, figs. 37—40.
1932 *Porambonites schmidti* NOETLING — SCHUCHERT & COOPER, p. 102, pl. 14, figs. 20—21, 27—28.

Material: One ventral and three dorsal interiors, about 15 complete specimens, most of them compressed, and a number of fragmentary valves.

Description: Outline rounded subpentagonal, with short, curved hinge-line. The dimensions for some perfectly preserved complete specimens are as follows:

Specimen	Zone	District	Length	Width	Thick-ness	Hinge line	Length/ width	Width/ thick-ness
34 428	Cycl.	Hadeland	32	36	35	6	0,89	1,02
34 277	-	-	42	45	33	8	0,93	1,36
33 859	Cycl.	-	40	42	32	5	0,95	1,31

The sculpture is not well preserved in any specimens, but it appears to be fine. The internal structures are quite well preserved, and are similar to those figured and described by NOETLING (1883) and SCHUCHERT & COOPER (1932). The vascular system is well developed in old valves (see above).

Remarks: As regards the interior, the Norwegian material seems to be identical with Baltic specimens of *P.* (*I*). *schmidti*. Due to the compression of most Norwegian specimens, it is difficult to discriminate between *schmidti* and *ventricosus*, but all the specimens which are not compressed seem to belong to *schmidti*, judging from their outline and proportions (see table of measurements above, and textfig. 2). The relatively large size of the specimens, and their low length width ratio indicate that they might belong to the younger variety of *schmidti*, intermediate between this species and *wesenbergensis*. This is even more probable as to some large specimens from zone 4bγ in the Oslo—Asker district (pl. 1, fig. 10) the largest of which is about 60 mm wide and with a length/width ratio of about 0,82. In the Baltic region such dimensions and proportions are found only in the Ashgillian *P.* (*I*). *gigas*. As mentioned above, it is very difficult to draw natural limits between the species in this group.

Distribution: According to ÖPIK (1930, p. 236), *P.* (*I.*) *schmidti* is rare in zone C3β, and common in D1 and D2 in Esthonia. It has been recorded from the Mjøsa districts by HOLTEDAHL (1909, pp. 25, 31, 41, 66, 67) and from the Upper Ordovician of Sweden by WIMAN (1908, p. 118). In the Oslo—Asker district it is found in zone 4bγ, generally in the middle part of the zone. Fragmentary and compressed specimens are found in the same zone in Ringerike. In the Northern part of Hadeland, and in Toten, there are a number of specimens from the Cyclocrinus beds, among them the specimens referred to by HOLTEDAHL (1909).

Porambonites (*Isorhynchus*) *cf. baueri* NOETLING 1883.

Pl. 1 figs. 5—6

cf. 1883 *Porambonites baueri* sp. n. — NOETLING, pp. 362—366, pl. 16.
cf. 1890 *Porambonites baueri* NOETLING — GAGEL, p. 51, pl. 5 fig. 3.
cf. 1921 *Porambonites baueri* NOETLING — BEKKER, pp. 80—81, pl. 4, figs. 5—6.
cf. 1930 *Porambonites baueri* NOETLING — TEICHERT, pp. 201—202. pl. 12, figs. 35—36 and fig. on p. 196.
cf. 1932 *Porambonites baueri* NOETLING — SCHUCHERT & COOPER, p. 102, pl. 14, figs. 8, 14.

Material: One specimen showing the interior of both valves, 5 complete specimens and a number of compressed specimens and fragments.

Description: A moderately large species with elongate, thick valves. The dimensions of some well preserved specimens are as follows:

Specimen	Zone	District	Length	Width	Thick-ness	Length/ width	Width/ thick-ness
34 535	Cycl.	Hadel. N.	40	35	31,5	1,14	1,09
34 297	-	-	42	33	34	1,27	0,97
	Coel.	Ringsaker	32	21	28	1,58(!)	0,75(!)
	-	-	33	26	28	1,27	0,93

The third specimen in the table shows no signs of being compressed, but the proportions are so deviating that one cannot be absolutely certain that no compression has taken place.

In accordance with the line of development described by TEICHERT (1930), the older specimens from the Coelosphaeridium zone are considerably smaller than the younger ones from the Cyclocrinus beds. The sides of the specimens are not quite parallel, like the specimens figured by TEICHERT (1930, pl. 12 fig. 35, and table on p. 226). As to outline the Norwegian specimens are intermediate between *baueri* and *deformatus-teretior*. The length/width ratio of the specimens all seem to fall within the range of *baueri* (see textfig. 2). The very low width/thickness ratio also indicates that the Norwegian specimens belong to *baueri*.

The interior is different from that of *P.* (*I.*) *schmidti* in that the septal plates in the dorsal valve are very short and thick, whereas those in the ventral valve are thick in their proximal part, and long, thin and placed closely together distally (pl. 1, figs. 5—6).

Remarks: The Norwegian specimens grouped into this species are somewhat heterogenous. In the specimens from the Coelosphaeridium beds in Ringsaker the dorsal valve is more curved than the ventral, and in this feature it resembles *P.* (*I.*) *teretior*. Both the length/width ratio and the width/thickness ratio are, however, different from typical specimens of that species.

The specimens from the Cyclocrinus beds in the northern part of Hadeland are more like the typical *baueri*, but they are larger than the Baltic specimens.

Distribution: As mentioned above, this species occurs in the Cyclocrinus beds in the northern part of Hadeland, and in the lower part of the Coelosphaeridium beds in Ringsaker. It is also found in the Mastopora beds in the Langesund—Gjerpen district.

Porambonites (*Isorhynchus*) sp.

In addition to the material described above, there is one single ventral interior from the Mastopora beds in the Langesund—Gjerpen district. It is about 30 mm long and 30 mm wide, moderately convex, and almost without sinus. The dental plates are rather thick, which indicates that it probably is an adult specimen. It has no stright hinge-line, and therefore belongs to the subgenus *Isorhynchus*. It resembles small, young specimens of *P.* (*I.*) *schmidti* in outline, but because of the small material, and the bad preservation, it is impossible to determine to which species it belongs.

Stratigraphic distribution.

As mentioned under the description of the species, *P.* (*P.*) *kjerulfi* belongs to the *intercedens* group of species, which died out in the Baltic region in the late Lower Ordovician. Representatives of this group of species are found in Middle Ordovician beds in Eire, Portugal, Southern France, and probably also in Sardinia and the Carnic Alps. *P.* (*I*). *schmidti* ranges from zone D1 to D2 in the Baltic Region, which corresponds roughly to zone 4bγ in the Oslo Region.

P. (*I*). *baueri* is found in D1 and the uppermost part of C3 in the Baltic Region, and in somewhat older deposits in the Oslo Region, in the Coelosphaeridium beds, probably corresponding to zones 4bα and 4bβ.

It is remarkable that the species found in the Oslo—Asker district mostly show Western European affinities, whereas the species found in the Langesund-Gjerpen district and the Ringsaker district are definitely Baltic. In Ringerike and Hadeland a mixture of both types are found. This is in accordance with the faunal assemblage

Stratigraphical and geographical distribution of Middle Ordovician Porambonitids in the Oslo Region.

SPECIES	HORIZONS CHASMOPS SERIES							LOCALITIES						
	4bα	4bβ	4bγ	4bδ	Coel	Cycl	Mast	Oslo—Asker	Langes.—Gjerpen	Ringerike	Hadeland	Toten	Hamar—Nes	Ringsaker
1) *P.* (*P.*) *kjerulfi*	1	1	–	–	–	1	–	1	–	1	–	1	–	–
2) *P.* (*I.*) *schmidti*	–	–	2	?	–	2	–	2	–	2	2	2	–	–
3) *P.* (*I.*) *baueri*	–	–	–	–	3	3	3	–	3	–	3	–	–	3
4) *P.* (*I.*) sp.	–	–	–	–	–	1	4	–	4	–	–	–	–	–

Abbreviations: Coel = Coelosphaeridium Beds, Cycl = Cyclocrinus Beds, Mast = Mastopora Beds.

in the districts, in the Oslo—Asker district the Middle Ordovician fauna is of a British type, whereas that of the Langesund—Gjerpen and Ringsaker districts is of a Baltic type. The two remaining districts show a mixed fauna (cf. STÖRMER 1953.)

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PLATE 1

EXPLANATION TO PLATE 1.

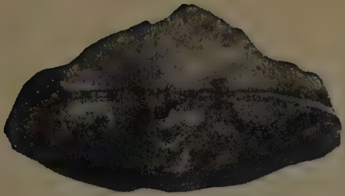
Figs. 1—4, 9 *Porambonites* (*Porambonites*) *kjerulfi* sp. n. *1*. A fragmentary specimen showing both teeth and accessory teeth. From zone 4bβ, Steilene, Oslo district. 1,3 x. 2—*4*. Three different views of the holotype, PMO 67 040. From zone 4bβ at southern point of Ildjernet, Oslo district. 1,1 x. *9*. Dorsal interior (artificial cast) PMO 67 042. From zone 4bβ at Steilene, Oslo district. 1,2 x.

Figs. 5—6. *Porambonites* (*Isorhynchus*) *cf. baueri* NOETLING 1883. Two different views of an internal cast of a specimen (PMO 67 041) from the Coelophaeridium zone, between Tørud and Bratberg, Ringsaker district (Coll. S. SKJESETH) 1,2 x.

Figs. 7—8, 10 *Porambonites* (*Isorhynchus*) *schmidti* NOETLING 1883. *7—8*. Two different views of a complete specimen (PMO 34 277) from the Cyclocrinus beds at Gjøvik, Gran, Hadeland. Coll. MÜNSTER. 1,15 x. *10*. Artificial cast of the interior of a very large valve (PMO 67 043) from the middle part of zone 4bγ at Billingstad, Asker district. 1,2 x.

PLATE 1

1



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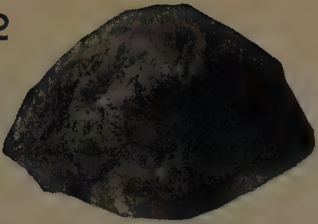

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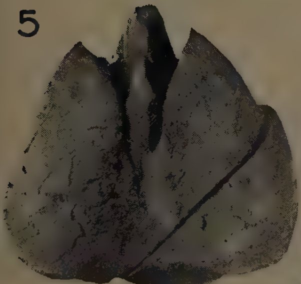

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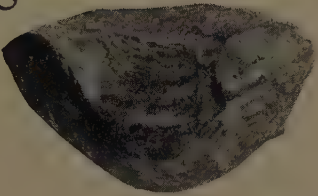

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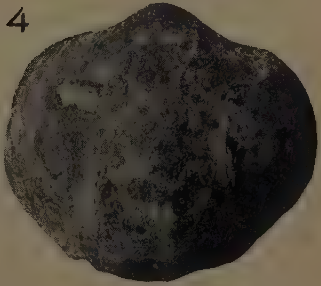

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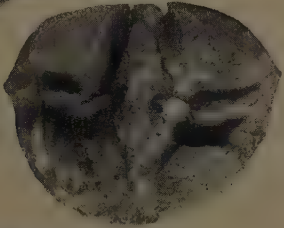

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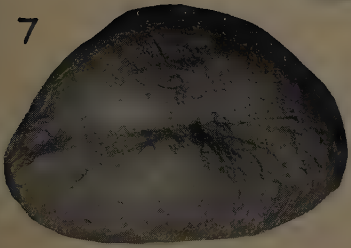

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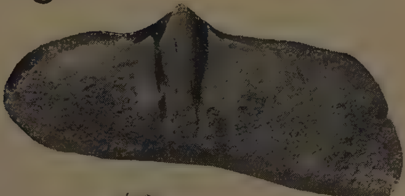

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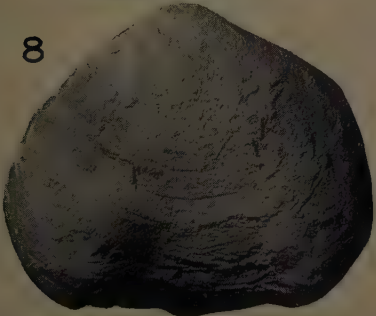

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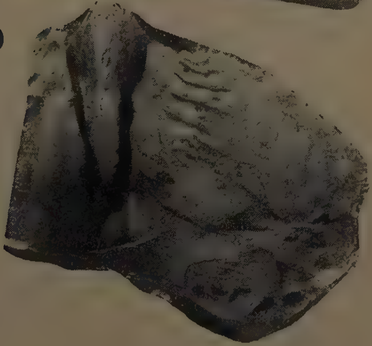

ON THE PETROGRAPHY OF THE SILURIAN SHALES FROM HADELAND, NORWAY

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Abstract. By means of microscope, X-ray, and D.T.A., constituents of the Silurian shales from Hadeland are determined to be: quartz, calcite, mica, chlorite and illite. Some chemical data are given, together with suggestions concerning the low phosphorous-content and the high manganese- and MgO-content in the same shales. The problem of red colour in shales from stage 7c is discussed briefly, as is an occurrence of speckled shale in the same stage.

Introduction.

This investigation is a part of a thesis for the degree of cand. real. at the University of Oslo. The stratigraphical part of the thesis will be printed as a separate paper. Therefore, only a short summary of the stratigraphy and structure will be given here.

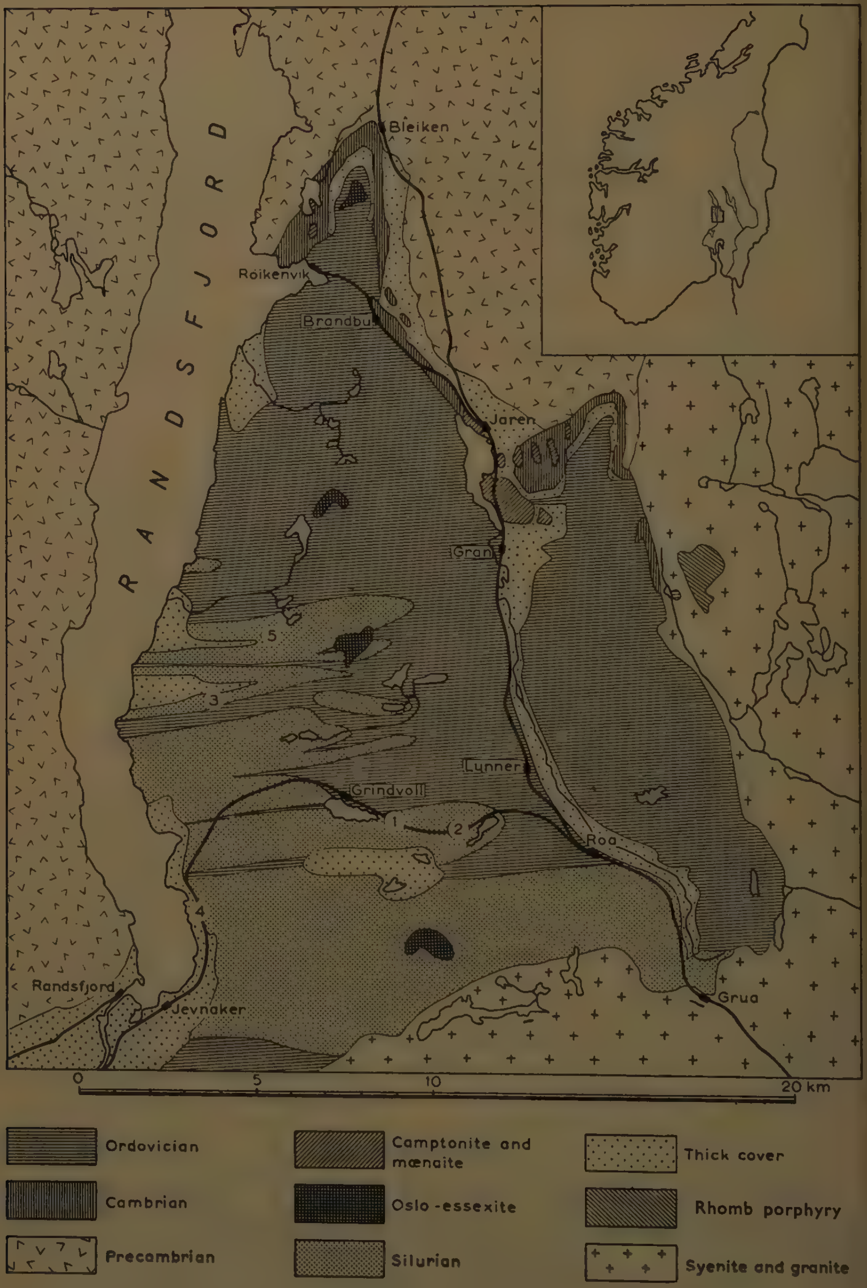

Fig. 1. Geological map of Hadeland.
Mainly after Kiær (1908) and Holtedahl and Schetelig (1923). Silurian drawn from my own observations. 1. Storskjæringa. 2. Askelsrud. 3. Heier. 4. Gulla. 5. Skattum.

The Cambro-Silurian district of Hadeland (fig. 1) is a sunken area. Its western boundary is marked by a N—S Permian fault along the Randsfjord; the southern continuation of this fault, trending SE, forms the boundary between the Ringerike and Hadeland districts, to the S and E there are Permian igneous rocks. In the NNE part of the area the Precambrian peneplane dips westward below the Cambro-Silurian sediments. The thick Silurian sandstones and limestones form large, gentle folds with an E—W strike.

Several geologists have visited Hadeland, but most of their work is of a stratigraphical nature. The petrography of the sediments has been dealt with in only a few papers. O. HOLTEDAHL (1917) gives a description and some chemical analyses of the economical important limestones in the area. In a later paper, the same writer (O. HOLTEDAHL 1927) gives values for the P_2O_5-content of some sediments from Hadeland.

MAJOR (1945) describes «Pipe-Rocks» in stage 6 from Hadeland. In connection with his studies of the oldest Silurian sediments of the northern part of the Oslo—Region (MAJOR 1946) he also examined the sediments occuring in stage 6 at Hadeland.

Fig. 2 is a schematic section through the Silurian sediments at Hadeland. The Silurian sequence begins with a sandstone (ca. 120 m thick), which is rather uniformly developed and contains very few fossils. The Gastropod-limestone (5 a), which underlies the sandstone, becomes sandier upwards. Ca. 3 m below the boundary between the sandstone and the limestone, a thin conglomerate occurs, which I have interpreted as a possible boundary between the Gastropod-limestone and stage 5 b.

Above the sandstone lies the Borealis-limestone (ca. 5 m thick) which is succeeded by the Penta-

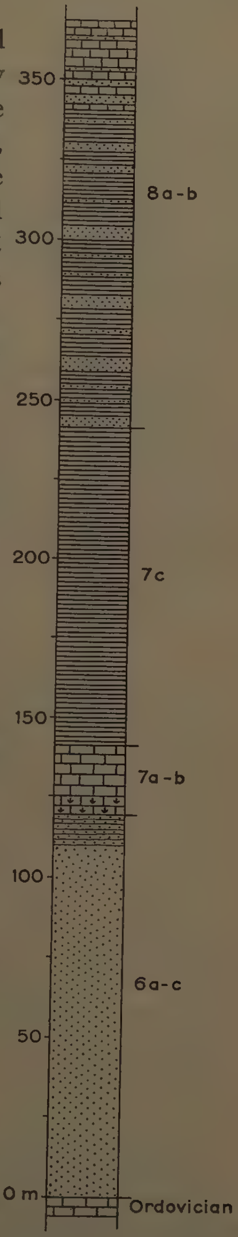

Fig. 2. Schematic section through the Silurian sediments at Hadeland.

merus-limestone, and the Upper Coral-limestone (ca. 11 m thick). All these limestones belong to stage 7a—b. The Upper Coral-limestone grades into the following units: 7c α—β Lower «Crotalocrinus» shale, 25—40 m thick and 7c γ Upper «Crotalocrinus» shale, 70—80 m thick. Some horizons with black, graptolitic shales, are found in stage 7c, and in the lower part of this stage, 4 bentonite beds occur. 7c is overlain by stage 8a—b, which consists of alternating olive-green shales, and sandstone beds.

Microscopic investigations.

The Silurian shales of the Hadeland district are very fine-grained, the grain-size mostly being less than the thickness of the thin sections. It has, therefore, been difficult to obtain satisfactory results from a study of such sections. Consequently, only the following 6 thin sections have been examined:

Sample 1. Black shale with graptolites (7c). From 29.30—31.30 m in the Storskjæringa section.
— 2. Green shale with limestone-lens (7c), near sample 1.
— 3. Red shale with mica (7c). At ca. 34.80 m, Storskjæringa.
— 4. Black shale with graptolites (7c). At 40.90—41.30 m, Storskjæringa.
— 5. Shale with graptolites (7c). Askelsrud.
— 6. Green shale (8a). At 20 m, Gulla.

In all these shales, quartz and calcite (possibly dolomite) are the dominant constituents, but several samples also contain mica and opaques. The size of the mineral fragments varies between 0.02 and 0.05 mm. They are sharp-edged and occur in a very fine-grained ground mass. The principal difference between the samples is the proportion of the constituents: quartz, calcite and mica.

X-ray.

X-ray analyses have been made of samples belonging to stage 7c at Askelsrud and Gunnstad. Also 3 samples from the transitional beds 7c—8a at Skattum have been examined. The X-ray examination has been undertaken at the X-ray laboratory of the Geological Museum. 9 cm camera and filtered iron radiation has been used.

All the samples give the same pattern, the films showing mainly quartz-, calcite- and mica-lines. There also appear some other, less characteristic lines. Among these there are two which are rather strong; one at 2.56 Å, and one at 7.07 Å. These values are in good accordance with the data published for chlorite.

Cand. real. E. Dahl has been so kind as to analyse a sample of shale from stage 8a, Gulla, on the X-ray spectrometer of the Chemical Institute at Blindern. This sample shows, among others, lines at 14.7 Å, 7.20 Å and 3.95 Å. This pattern is typical for chlorite; but the lines might also be produced by a mixture of a 14 Å and a 7 Å mineral. Therefore the sample was treated with 2 N HCl at 100° C for 1 hour and then examined again. The lines at 14 Å and 7 Å disappeared and the line at 3.59 Å was replaced by a weak line at 3.56 Å. This indicates chlorite. The other lines, caused by quartz, mica and possibly feldspar, become more distinct. The X-ray examination thus indicates that the shales consist mainly of quartz, calcite, mica, chlorite, and possibly feldspar.

Differential thermal analyses (D.T.A.)

In order to determine the composition of the fine ground mass in the shales I have made several differential thermal analyses. These analyses have been carried out at the soil laboratory of the Norwegian Geological Survey, in cooperation with State Geologist R. Selmer-Olsen. Each sample was ground until the maximum grain-size did not exceed 20 μ. For each D.T.A. ca. 0.5 g of the ground sample was used.

The D.T.A. apparatus is built mainly after the instructions given in Spiel, Berkelheimer, Pask and Davies (1945). The furnace-system is closed and has a permanent arrangement of the specimen holder and the thermoelement. A Pt-PtRh10%-Pt differential thermocouple is used. As inert comparison powder, α-Al_2O_3 is used. The temperature rises 10° C per minute. In the beginning, the apparatus did not have an automatic heat regulator and recording unit. However, when the apparatus was made automatic, the original arrangement was kept intact. The following samples were analysed before the apparatus became automatic: No. 1, 3, 4, 5, 6, 7, 11, 12, 13, 14, 15, and 16.

D.T.A. has not been used heretofore in the examination of our Cambro-Silurian shales. I shall, therefore, give a rather thorough description of the results obtained.

The following samples have been analysed (Plates I—V): (For comparison purposes 3 samples from Mjøsa and Ringerike and 2 samples of chlorite have also been examined).

1. 7b, at 25.40 m, Heier.
2. 7c, at 34.80 m, Storskjæringa.
3. 7c, at 7 m, Gulla.
4. 7c (green), Gunnstad.
5. 7c, Askelsrud.
6. 7c, Eksbakken, Mjøsa.
7. 7c, Vik, Ringerike.
8. 8a, at 1.20 m, Gulla.
9. 8a (HCl), at 1.20 m, Gulla.
10. 7c—8a, Skattum.
11. — —
12. — —
13. 8 ?, Vassjø.
14. 8a, Garntangen, Ringerike.
15. Chlorite, Gravdal.
16. — , Snarum.

ENDOTHERMIC REACTIONS AT 100°—200°C.

All the curves have one endothermic peak in the 100°—200° temperature range. However, in most of the curves, this peak is rather small, its maximum varying between 100° and 150°. It must, however, be said that the D.T.A. apparatus used, is not built for exact investigations of reactions at such low temperatures, and the results obtained do not, therefore, allow any far-reaching conclusions.

It is customary, when examining D.T.A. curves of clay and clay minerals, to find that more or less distinct endothermic reactions appear between 100° and 200°. Generally these reactions are interpreted as loss of water adsorbed by the mineral particles in the clay.

EXOTHERMIC REACTIONS AT 250°—550°C.

At these temperatures all the curves show one or more exothermic reactions. Some of the peaks are very broad, and the maximum of the reactions varies through the whole temperature range. Sample 1. has the lowest maximum temperature (250°), and also has an exothermic reaction with the maximum at 320°. Such double peaks are also observed in several of the other curves, but in these the maximum for the first peak comes at a little higher temperature than in sample 1. In sample 4., the two peaks occur at 340° and 510°; sample 6: 330° and 410°; sample 8: 320° and 450°; sample 9: 330° and 550°; sample 12: 330° and 460°; sample 13: 330° and 440° (this sample also shows a little exothermic reaction at 490°); sample 14: 350° and 480°.

Maxima for most of the curves are found in the 310°—350° interval. The curves having two peaks, reach their second maximum in the 410°—510° interval.

These peaks are probably caused by the combustion of organic matter and/or iron sulphide. GRIM and ROWLAND (1944, p.13, 19) found that the combustion of organic matter takes place at temperatures of 200°—700°, and causes a broad exothermic peak which might mask other reactions. The above mentioned authors also found that pyrite and marcasite give a distinct exothermic peak at 400°—550° and a weaker endothermic peak at 600°—700°.

ENDOTHERMIC REACTIONS AT 550°—700°C.

In this interval all the curves have a broad and very characteristic endothermic peak. The peak maximum varies between 570°—620°. Generally, a broad peak at these temperatures is interpreted to be caused by clay minerals. Members of this group which give endothermic reactions in this interval are: all mica-like clay minerals (except vermiculite), kaolinite, anauxite, halloysite, endellite, beidellite and nontronite. However, most of these minerals are relatively rare, and only a few of them have been found in Paleozoic sediments. The most probable minerals in our Cambro-Silurian shales are: illite, montmorillonite and kaolinite. Montmorillonite, however, ordinarily produces a peak at a little higher temperature (50°—100°), and except for beds of probable bentonitic origin, this mineral has not yet been observed in Paleozoic sediments (GRIM 1953). When considering the possibilities for kaolinite, it must be pointed out that the peak caused by kaolinite is ordinarily relatively deep and sharp. The curves are more characteristic for illite in that they have lower and broader peaks. It seems probable, therefore that the clay mineral present is illite. GRIM (1953) reports that illite may give peaks within the 550°—650° temperature range. These peaks are connected with loss of water from the lattice.

Most of the published D.T.A. curves for illite show a peak maximum at a little less than 600°, whereas the samples from Hadeland have a peak maximum above 600°.

The X-ray examinations have shown that chlorite is present; consequently one cannot exclude the possibility that this peak is caused by that mineral. Therefore, for purpose of comparison I have included two samples of chlorite, analysed by State Geologist R. Selmer-Olsen (sample 15 and 16). These curves show a strong and very distinct endothermic reaction at 630° and one at ca. 800°. According to GRIM (1953, p.239), many analysed samples of chlorite show a very sharp reaction in the 500°—700° range. Most of these also have a sharp endothermic reaction at ca. 800°. This accords well with the results obtained by Selmer-Olsen.

These data, however, are from well crystallized chlorites, and variation in the clay mineral chlorites might occur. GRIM (1953, p.239) suggests, however, that clay mineral chlorites would show the same thermal reactions as well crystallized chlorites, but perhaps at somewhat lower temperatures.

In order to determine whether the strong endothermic reaction shown by most of the samples is produced by a mixture of illite and chlorite, or only by chlorite, I treated the sample from stage 8a at Gulla with HCl. This treatment should destroy the chlorite. The acidized sample gives a curve which is much smoother than that produced by the untreated sample from the same locality. The two exothermic peaks in the 200°—550° temperature interval become more pronounced and, at the same time, the broad peak at 615° is divided into two, a small one at 590° and a broad one at 655°. This may be interpreted in the following way: in the untreated sample, chlorite masks the small peak at 590°, which peak possibly indicates a small content of illite. The 655° peak may be connected with the possible iron sulphides (giving the peak at 550°), and might have been covered in the untreated sample.

The same effect has also been observed in my investigations of Silurian bentonites from the Oslo—Region.

ENDOTHERMIC REACTIONS AT 700°—900°C.

In the 700°—900° temperature range all curves indicate a more or less sharp endothermic reaction. The sharp peaks at ca. 850° are certainly due to calcite. As to the temperature of dissociation for calcite and dolomite, different scientists have reached some divergent conclusions. Norin (1941, p. 222), Kerr and Kulp (1948, p. 407) and several others have found that calcite gives a peak at 960°—990°, whereas others (Cuthbert and Rowland, 1947, p. 113; Grim and Rowland, 1944, p. 10) found the peak maximum to be ca. 120° lower.

The dissociation of dolomite occurs in two steps. According to Grim and Rowland (1944, p. 13) the first maximum is found in the 730°—800° interval; the other occurs at the same, or a little lower temperature as for calcite. Soveri (1950) has analysed mixtures of calcite and clay and found that the maximum varied between 775° and 860°, when the calcite content varied from 2 % to 15 %. It seems, therefore, that the maximum is dependent on how much calcite the sample contains.

Rough investigations show a rather high percentage of $CaC0_3$ in the shales from Hadeland. The peak maximum should, therefore, be expected at a rather high temperature. It may be noticed that in the acid treated sample from stage 8a, Gulla, no peak occurs in this interval.

In connection with the sharp calcite peak there is also a strong exothermic reaction. Reactions at such high temperatures are difficult to interpret and at present there is some uncertainty as to what happens.

In summary, the D.T.A. investigations indicate that the fine groundmass consists mainly of chlorite, illite and calcite.

Chemical composition.

Only a very few analyses of Cambro-Silurian shales from the Oslo—Region have been published, so little is known about the exact composition of these sediments. KVALHEIM (1949), however, has published analyses of two Silurian (7c *a*) shales from Askelsrud (Hadeland) and Sandvika, in the Oslc—Region. (Tab. 1). From these analyses it is apparent that there are certain differences in the chemical composition of samples from the two localities.

Table 1.

	7c *a* Askelsrud	7c *a* Sandvika
SiO_2	50.91	42.13
TiO_2	0.94	0.86
Al_2O_3	15.62	12.98
Fe_2O_3	4.40	3.36
FeO	3.15	2.79
MnO	0.20	0.33
MgO	3.50	3.07
CaO	7.27	15.89
Na_2O	0.91	0.70
K_2O	3.71	2.80
P_2O_5	0.07	0.07
S	0.05	0.38
CO_2	5.47	12.37
C	0.15	0.04
H_2O — 110° C	0.40	0.53
H_2O + 110° C	2.68	1.70
	99.43	100.00
— O for S	—	0.09
	99.43	99.91

(Analyst B. Bruun)

I have determined the content of some elements in a green shale with dark dots, which occurs at ca. 25.40 m in the Heier section. (Tab. 2). The analysis was made in order to determine whether or not the dark dots were phosphorite. A complete silicate-analysis was, therefore, not carried out. The low phosphorous content, however, excludes the possibility of phosphorite, but the loss on ignition indicates an organic origin of the material.

Table 2.

Fe_2O_3 FeO	8.33
MgO	4.38
CaO	4.17
P_2O_5	0.05
Loss on ignition	6.38

O. HOLTEDAHL (1927) gives determinations of the P_2O_5 content in two shale samples from stage 7c, Hadeland. The localities are labelled: East of Grindvoll st. Probably the samples were taken in the railway-cutting called Storskjæringa. The phosphorous content of the two samples shows considerable differences; one (from the upper part of 7c) contains 0.14 % P_2O_5, whereas the other has only 0.075 % P_2O_5. The last value accords well with those Kvalheim and I have found. O. HOLTEDAHL (1927) gives 0.16 % P_2O_5 as average for the shales from stage 7—8 in the Oslo-Region. This average includes, however, one sample from Bærum which shows an exceptionally high (0.64 %) P_2O_5 value. If this sample is omitted, the average for the 7 other samples analysed, is 0.094 %, which seems to be in better accordance with figures from other analyses. If Kvalheim's two analyses and mine from Heier are taken together, with the corrected average from Holtedahl, the average becomes: 0.085 % P_2O_5. Holtedahl reports an average P_2O_5 content of 0.21 % for Norwegian Quarternary clays. He also cites CLARK (1924) who has found the P_2O_5 average of 51 analysed Paleozoic shales to be 0.15 %. The phosphorous content of the shales from stages 7 and 8 is, consequently considerably lower than common in other Paleozoic shales. An explanation for this may be found in the circumstance that phosphorous seems to be particularly abundant in deep-sea sediments (LANDERGREN 1954) whereas geological evidence (ripple marks etc.) indicates that the red shales in stage 7c from Hadeland were deposited in relatively shallow water.

Another interesting feature of the two analyses is the rather high content of manganese (0.20 % and 0.33 % MnO). GOLDSCHMIDT (1954) gives the average MnO content in 36 Paleozoic shales to be 0.12 % and the average of 78 Norwegian Quarternary clays is 0.11 %. An explanation for the relatively high Mn content in the red Silurian shales is probably to be found in the geochemical properties of manganese. According to GOLDSCHMIDT (1954) the fate of manganese by weathering depends on two chemical processes: one, a leaching of di-valent manganese in solution, mainly as bicarbonate; the other, a precipitation of very insoluble hydroxydes and oxydes of 3- and 4- valent manganese.

In the case of natural compounds of manganese, the lowest stage of oxidation produces the most mobile irons. This is a result of the fact that the ionic-radius of divalent manganese is relatively large, leading to a low ionic potential for Mn^{2+}. Divalent manganese, therefore, will be more susceptible to leaching even by very weakly acid solutions. 3- and 4-valent manganese has a much higher ionic potential. This will lead to precipitation from even rather acid aqueous solutions.

The red colour of the shales in 7c suggests that they were deposited under aerobic conditions. Therefore, during deposition the manganese could have been oxidized to a higher state, leading to its precipitation.

The analyses also show a rather high MgO content in relation to the Al_2O_3 content. This may indicate that the samples contain dolomite, but there are also other possibilities.

GOLDSCHMIDT (1926) has pointed out that a high content of MgO in relation to Al_2O_3 in clay sediments indicates that the sediment was derived from a magnesium-rich rock, and he has also shown that in the Ogygiocaris-shale of the Oslo-Region there is a rather high content of Mg. This is interpreted to suggest a possible supply of volcanic ash from vulcanism in the Trondheim-area. He reports that the Al_2O_3/MgO ratio is about 10 in our oldest Paleozoic shales (e.g., the Phyllograptus-shale), whereas for the Ogygiocaris-shale it is 3—4. For the two analysed samples from stage 7c, the relation between Al_2O_3/MgO is ca. 4.5 and 4.2 for Hadeland and Sandvika respectively. I suggest that this may be connected with the vulcanism that produced the bentonite beds in stage 7c.

The conclusions reached are based on only a few analyses, consequently, the results must be regarded as preliminary.

The problem of red colour in shales from stage 7c.

The significiance of the red colour of sediments is a much debated problem. The colouring matter of such sediments is ferric anhydride (ocherous hematite), (PETTIJOHN, 1949, p.170). Several authors

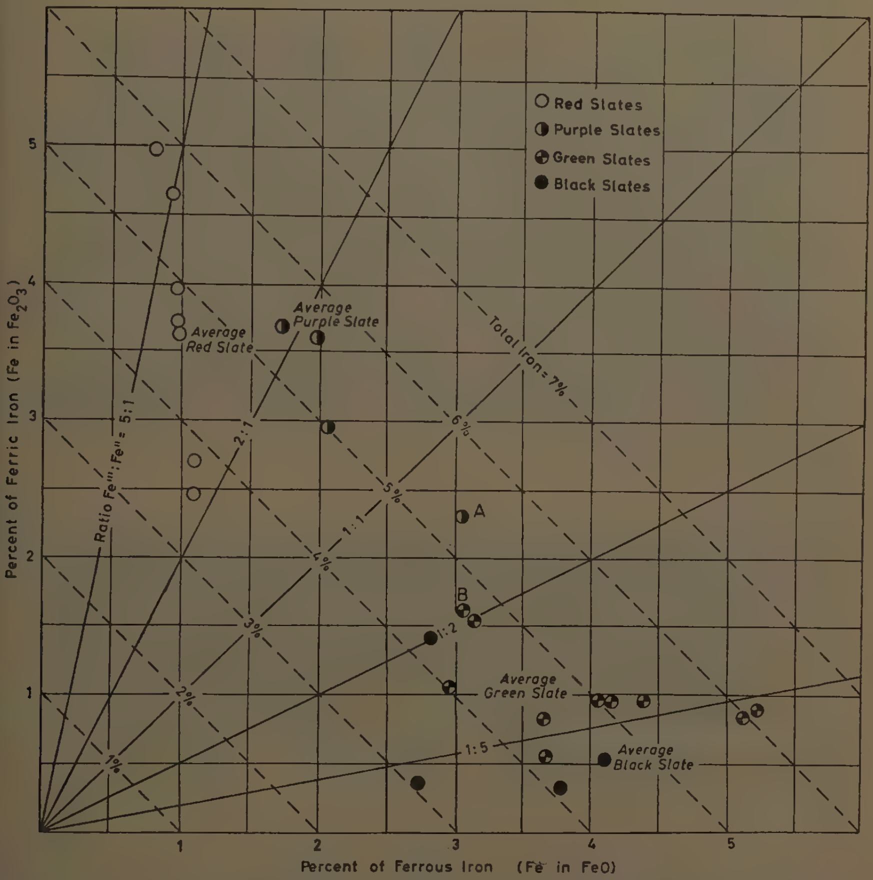

Fig. 3. Relation of ferrous-ferric iron to colour of slates. After Pettijohn (1949, p. 171). Analyses of the iron content in two samples from Gunnstad (Hadeland) are also plotted. A. red shale. B. green shale.

have shown that red sediments do not contain more iron than sediments of other colours (fig. 3).

Analyses of the iron content in samples from Hadeland are shown in table 3., and plotted in fig. 3.

Table 3.

	7c (green) Gunnstad	7c (red) Gunnstad	7c (grey) Askelsrud
FeO	3.05 %	3.03 %	3.26 %
Fe_2O_3	1.53 %	2.32 %	1.28 %
Total	4.58 %	5.35 %	4.54 %

The problem of the red colour is one of finding conditions under which dehydration of ferric oxides can occur, rather than determining the conditions under which ferric oxide is produced.

It is commonly assumed that the red oxide present was deposited in this state. After thorough investigations, DORSEY (1926) concluded that dehydration must have taken place before deposition, suggesting that such a reaction should be contingent upon a warm, moist climate. Furthermore, in order to retain the red colour, the sediments must have deposited subaerially or in areas where there was no reduction in greater scale. He concludes that this may be the reason why red sediments are, in most cases, continental. Most sediments are carried to the sea where they are subject to reducing agents caused by the decay of marine organisms. The fact that marine red beds are sometimes found suggests that real marine conditions — the reducing agencies — have been pushed off the coast contemporary with deposition of the sediment. Dorsey believes that this will result in red «wedges» in the marine sediments. Such conditions have been observed, for example in the Atlantic near the mouth of the Amazonas (MURRAY, 1891, p.234).

Dorsey mentions that such shifts are inclined to be periodical and it is therefore possible to find fossils of marine animals which have been «buried» in these brackish sediments. As an example he mentions red Silurian shales from the eastern part of N. America in which brachiopods are found.

Sections through stage 7c at Hadeland show an alternation of green and red beds. The total thickness of the green beds is greater than that of the red beds. If the green beds are primary, and there is nothing to contradict such an assumption, a periodical shift as proposed by Dorsey seems to fit quite well with the conditions at Hadeland.

The fact that brachiopods, crinoid stems etc. are found in the red beds at Hadeland, however, does not necessarily mean that these animals lived just there. In other localities in the Oslo-Region (Gjettum, Slependen etc.) it can be shown that crinoid stems, corals etc. were washed together after death by strong currents.

Speckled shale.

South of Tømmerås is found a small exposure of graptolitic, dark shale in which there are small grey-green lumps. The lumps have the form of small lenses, branches, and flat worm-like bodies,

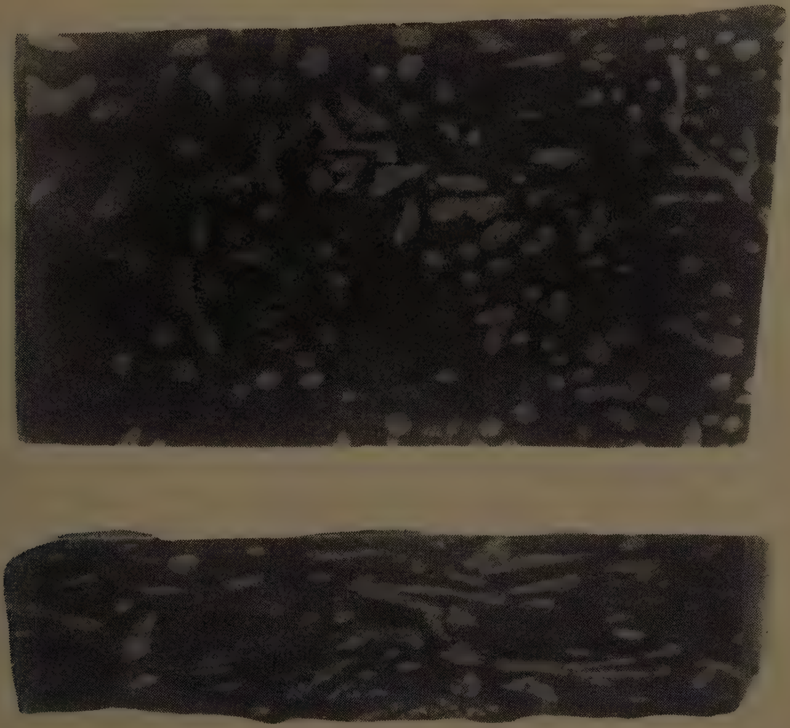

Fig. 4. Upper, a piece of speckled shale from Tømmerås, which has been polished parallel to the bedding planes. Lower, the same piece polished normal to the bedding planes. Both ca. 2.5 X.

and their greatest extension parallel to the bedding planes. The boundary between the dark shale and the lumps is sharp (fig. 4).

No difference between the dark shale and the lumps is seen in thin sections. The rock consists of a very fine-grained groundmass in which small (0.02 mm), sharp quartz fragments appear to be relatively abundant. Opaques and one plagioclase fragment (ca. 30 An) are also observed.

In cores from the deep borings at Kinnekulle HENNINGSMOEN (1948) observed that, in the Tretaspis series, speckled shale occurs between dark shale and grey-green mudstone. From dark shale to speckled shale there is a gradual transition; the speckled shale then changes into grey or grey-green shale. The fauna found in the speckled shale is a mixture of the faunas found in the dark and the grey shales. Henningsmoen assumes that the lumps are primary and concludes that the speckled shale developed when the sediments were deposited and when conditions, at least near the bottom, were alternating between stagnant and ventilated conditions.

The investigations from Kinnekulle show that the rhytmic alternation between stagnant and ventilated conditions is perhaps only a local phenomenon, for the speckled shale does not seem to be common in corresponding layers outside Kinnekulle. As a possible explananation, Henningsmoen visualizes a basin in which renewal and aeration of water at times could cause more ventilated conditions. Considering that the foul water was probably overlain by a layer of ventilated water, as indicated by the rich planktonic fauna, another possible explanation is that here the (somewhat oscillating) boundary between the layers of water lay near the bottom.

It is difficult to make definite conclusions as to conditions during the deposition of the speckled shale at Tømmerås, because the shale is found only in a very small exposure. It is therefore impossible to get an impression of the transitional beds. The nearest exposure, ca. 10 m South, shows only red shale belonging to 7c. It seems probable, however, that an explanation similar to the one given for the speckled shale at Kinnekulle may also apply in this case. In the Storskjæringa section there are found some beds with dark graptolitic shale which indicate that an alteration of the depositional conditions took place during this period.

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PLATES I—V

D.T.A. CURVES

PLATE I

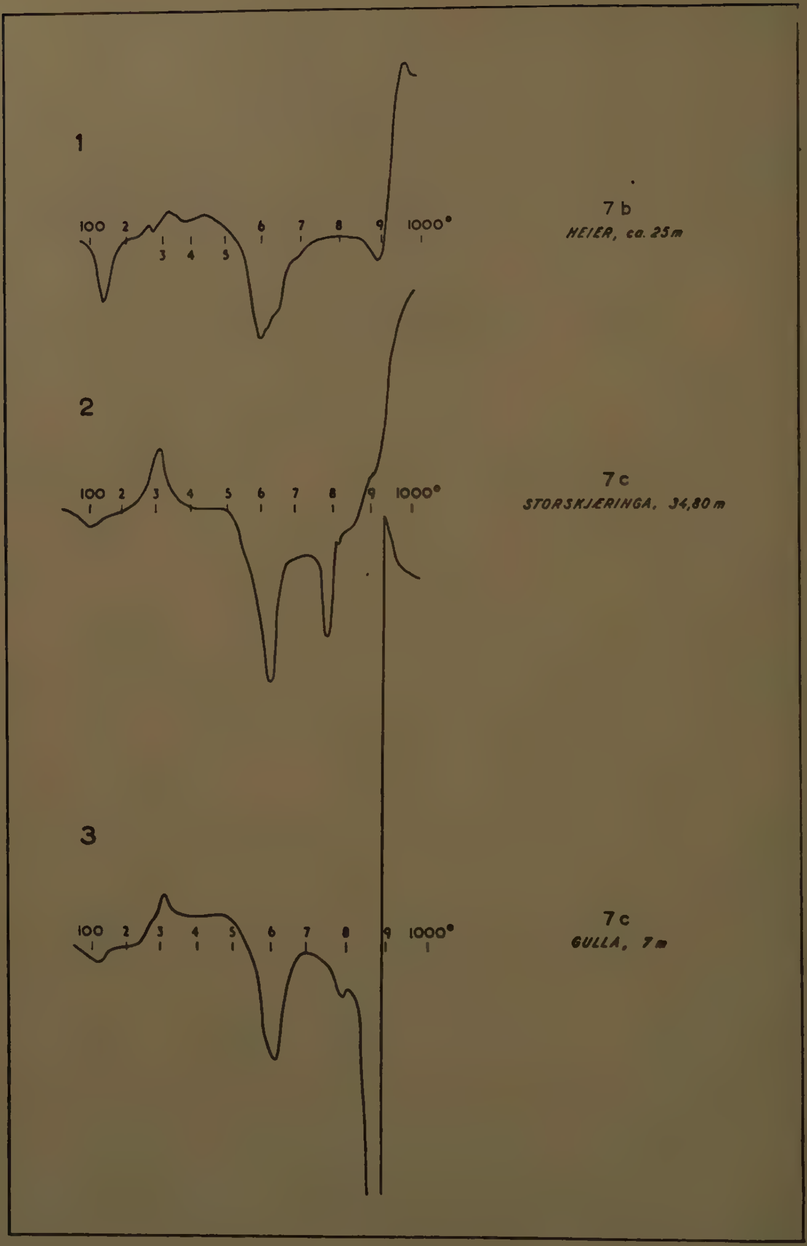

1
100 2 3 4 5 6 7 8 9 1000°
7 b
HEIER, ca. 25 m
2
100 2 3 4 5 6 7 8 9 1000°
7 c
STORSKJÆRINGA, 34,80 m
3
100 2 3 4 5 6 7 8 9 1000°
7 c
GULLA, 7 m

PLATE II

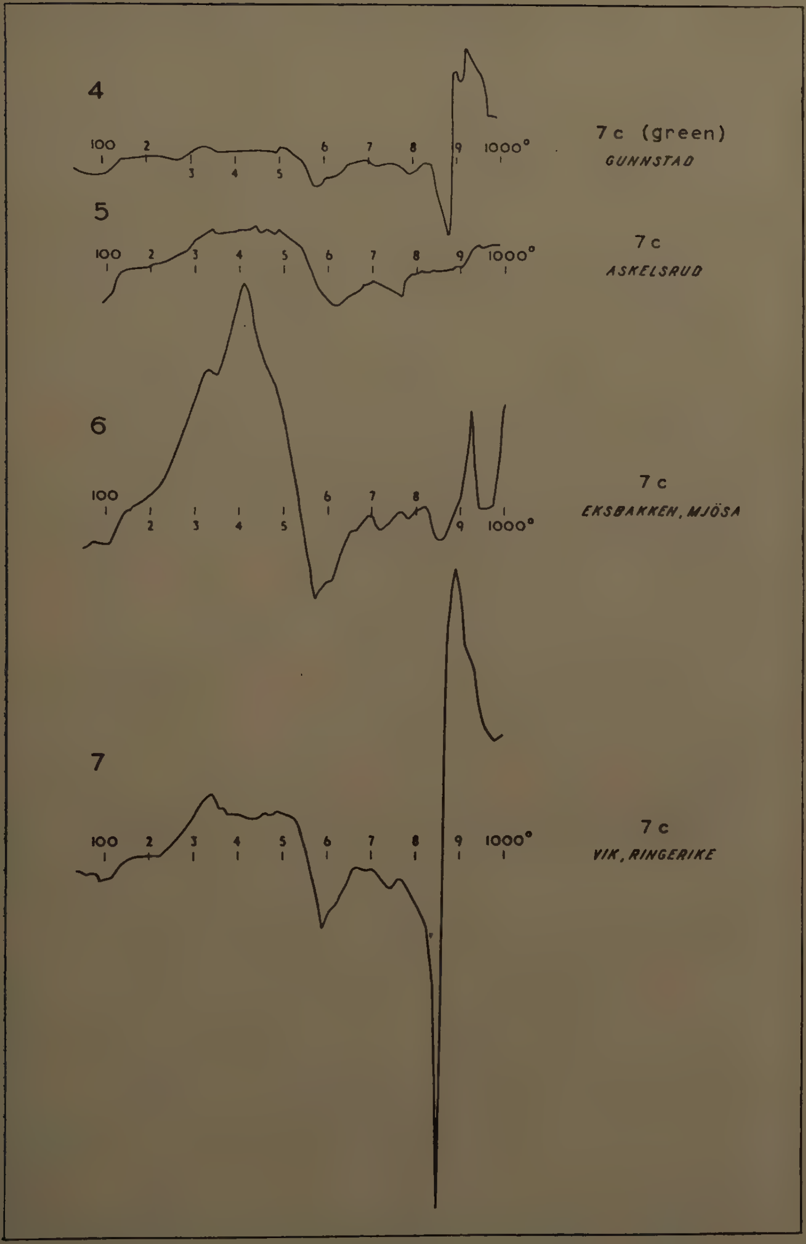
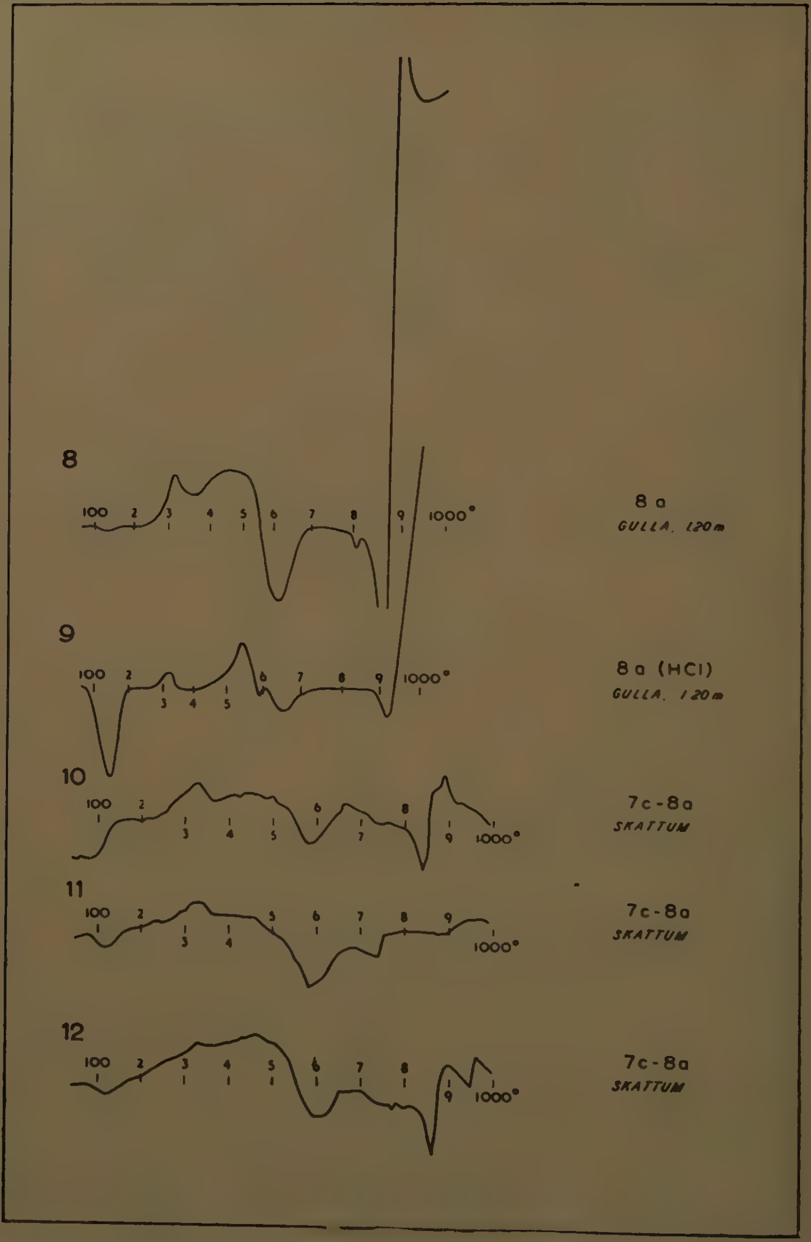

4
100
2
3
4
5
6
7
8
9
1000°
7 c (green)
GUNNSTAD
5
100
2
3
4
5
6
7
8
9
1000°
7 c
ASKELSRUD
6
100
2
3
4
5
6
7
8
9
1000°
7 c
EKSBAKKEN, MJÖSA
7
100
2
3
4
5
6
7
8
9
1000°
7 c
VIK, RINGERIKE

PLATE III


8
100 2 3 4 5 6 7 8 9 1000°
8 a
GULLA. 120m
9
100 2 3 4 5 6 7 8 9 1000°
8 a (HCl)
GULLA. 120m
10
100 2 3 4 5 6 7 8 9 1000°
7c-8a
SKATTUM
11
100 2 3 4 5 6 7 8 9 1000°
7c-8a
SKATTUM
12
100 2 3 4 5 6 7 8 9 1000°
7c-8a
SKATTUM

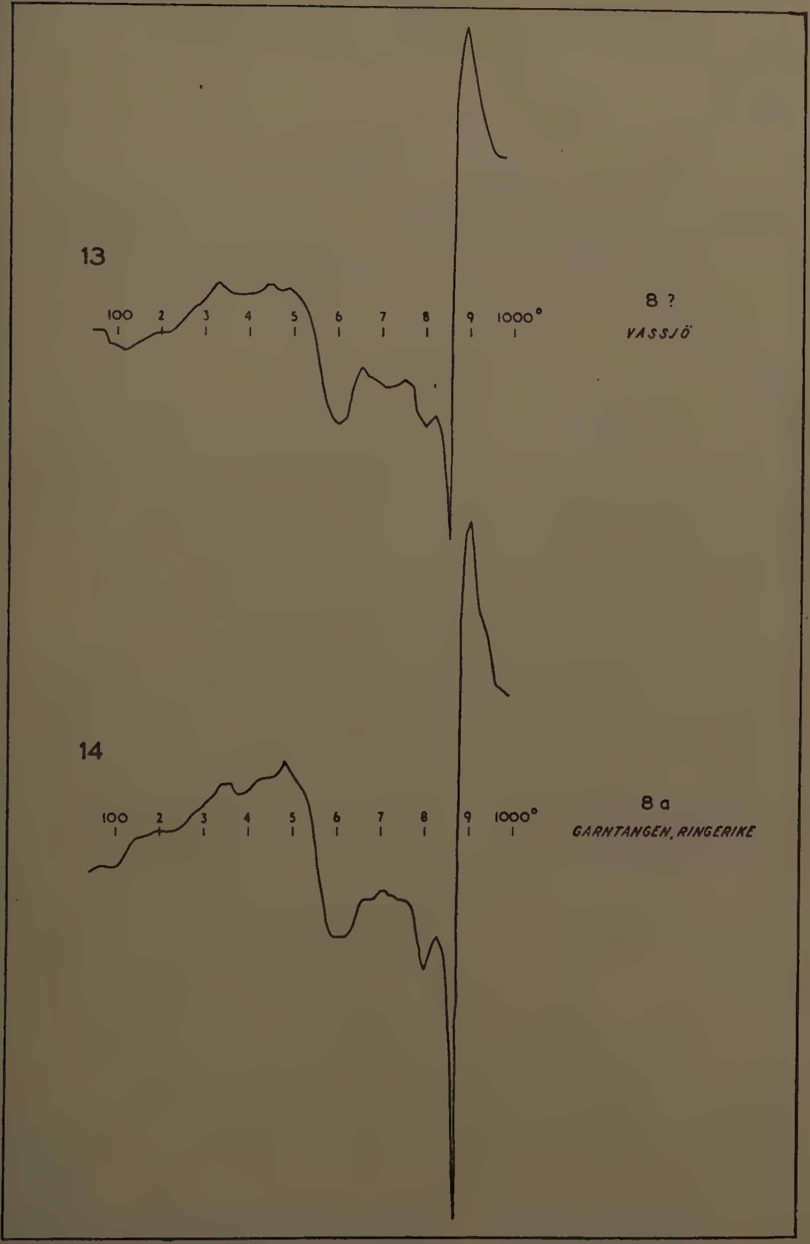
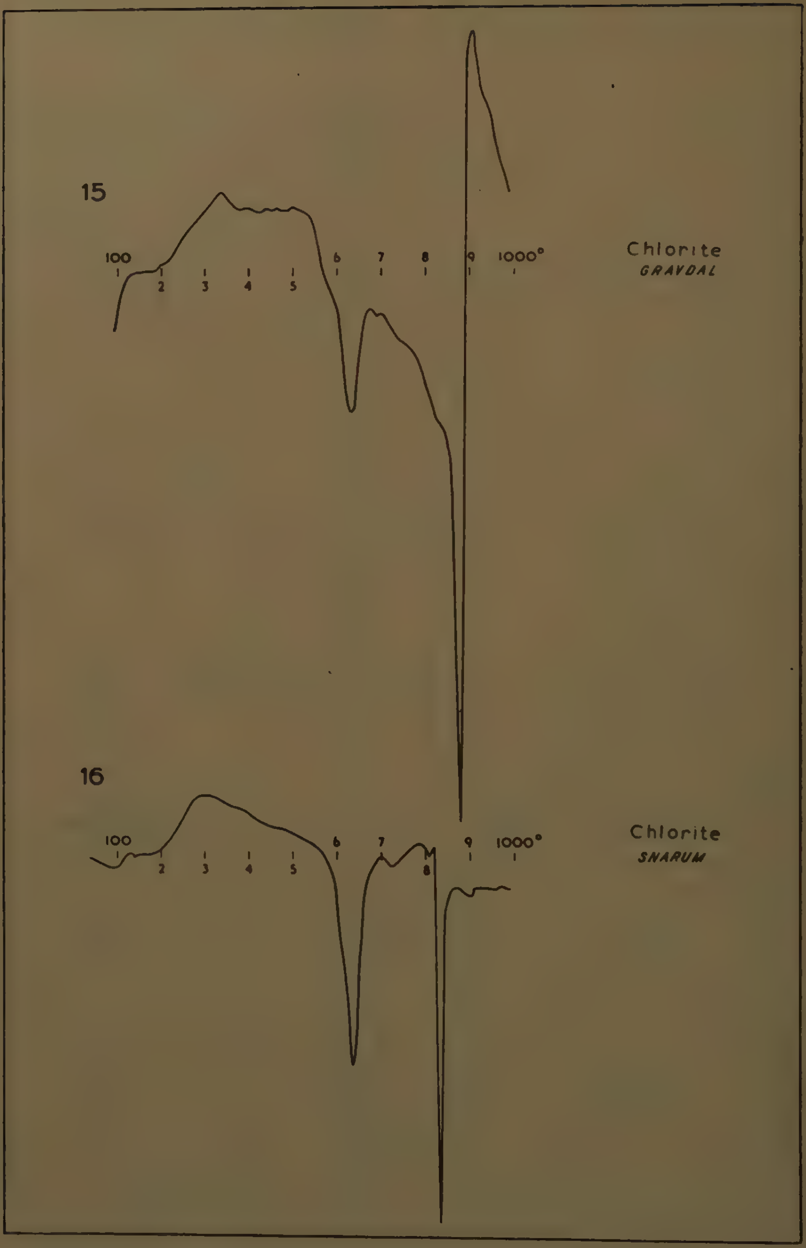

13
100
2
3
4
5
6
7
8
9
1000°
8 ?
VASSJÖ
14
100
2
3
4
5
6
7
8
9
1000°
8 a
GARNTANGEN, RINGERIKE

PLATE V



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CONNECTIONS BETWEEN THE TRONDHEIM AND SUNNHORDLAND REGIONS, CALEDONIDES OF NORWAY

By

IVAR HERNES

The traditional view put forward in Norwegian geological discussions has been to draw the links between the Trondheim region and the coastal area south of Bergen over the Jotunheim region. On the other hand an essential difference has been claimed to exist between the Trondheim region and the Jotunheim region. In actual fact there are a number of circumstances which show that the connection between the Trondheim region and Sunnhordland does not run via the Jotunheim region, but via the Devonian synclinal area of Vestlandet.

On this view the Caledonian mountain range forms a great arc pushing into Central Norway, having its convex side towards the southeast and to southward passing over into an arc with its concave side to the southeast. Such an arcuate mountain chain would provide an explanation of the complex folding systems that we encounter in the chain. In the following paragraphs I shall discuss features which throw light on the relationship between such an arcuate mountain range and the geology of Norway.

The Trondheim Region and Vestlandet.

TH. VOGT, in his important studies on the structure of the Caledonides, pointed out the existence of a direct connection between the Trondheim region and the Devonian synclinal area of Vestlandet (1928, 1954 a, 1954 b, 1954 c). The westsouthwesterly fold system which links these two areas together occupies a prominent place in Vogt's tectonic analysis. An important feature is the syncline which he traces between the Dombås area of the Trondheim region and the Devonian rocks of Hornelen. The axis of this syncline runs parallel with that of the more northerly situated Trondheimsfjord syncline.

This westsouthwesterly fold system is further discussed in my paper on the main stratigraphic and tectonic features along the Trondheimsfjord syncline (I. HERNES 1956 c). I concluded by saying that the Trondheim region was directly continuous into the Western Gneiss area, and that the westsouthwesterly fold system probably constituted the main line of the Caledonides in this area.

The Devonian synclinal area of Vestlandet is a most interesting region both petrographically and tectonically. N.-H. KOLDERUP (1928) has published a geological map of the area. The investigations have recently been continued and an interim report has been published (1955).

I had the opportunity to take part in these investigations on the Devonian synclinal area and I intend in the next few paragraphs to give a brief account of some of the points arising from this work which are of interest for our present study. The area is reminiscent, of the Trondheim region in character. Petrographically, for example, I would mention the occurrences of greenstone, pyrites and Caledonian intrusives.

The transition between the Devonian synclinal area of Vestlandet and the Western Gneiss area calls to mind, both in petrography and structure, the western boundary of the Trondheim region south of the Trondheimsfjord syncline. A connection between those two border areas would reach its culmination in Sunnmøre—Romsdal.

A closer study of the most western part of the Trondheimsfjord syncline would be of intrinsic interest in an evaluation of such a culmination. The Trondheimsfjord syncline, which can be followed down the Surnadal and further over Tingvoll—Molde (HERNES 1956 a, 1956 b), is described, in its westward continuation, by T. GJELSVIK (1951).

From the Trondheimsfjord syncline and northward the structurally determined westsouthwesterly trend is very pronounced. Southwards, towards the Jotunheim region, this structural westsouthwesterly trend appears to become steadily less and less dominant. We are here approaching an area where Caledonian nappes overlie pre-Eocambrian rocks, with the possibility of finding traces of a pre-Caledonian structure (K. LANDMARK 1949).

Let us now return to the Devonian synclinal area of Vestlandet. Here we are in a very complex region. In addition to the main W — E trend, which links up this region with the Trondheim region, we also find a pronounced N — S trend. This is especially prominent in the Old Red deposits which, showing a clear W — E major trend, cccur in a belt trending N — S. The geological conditions further south along the coast show that the N — S trend becomes steadily more pronounced southwards, whilst the W — E trend gradually dies away.

Not the Old Red sediments alone, but also the underlying rocks, occur along the coast of Vestlandet in a N — S trending belt. The Devonian, as is known, is found as far south as the Bergen arcs. Greenstone, pyrites and Caledonian intrusives can be seen as far down as the Stavanger district. The anorthosites, near and between the Devonian of Hornelen and Håsteinen, I regard as a complex equivalent to the anorthosites of the Bergen arcs.

In the north we find arcs with a W — E trending structure pattern, which southwards become progressively more and more drawn out in a N — S direction. This is in good agreement with the theory of an arcuate mountain chain showing the effects of pressures from both the north and the west. The Devonian synclinal area, on this view, would thus constitute the transition from a westsouthwesterly to a N—S primary trend of the Caledonides. O. Holtedahl (1944, p. 22) also assumes a primary N — S trend of the Caledonides in the Haugesund—Stavanger district.

An interesting point about the Devonian synclinal area is that we find preserved here Caledonian nappes overlying rock complexes intensely folded during the Caledonian orogeny. The Devonian of Kvamshesten is particularly interesting, with the associated and underlying mangerite — syenite nappe, as also the overthrust gabbro on the Devonian of Solund (C. F. Kolderup 1925). The direction of thrust in the latter area has not yet finally been determined but is assumed to be approximately east or southeast.

A. Kvale (1953, map fig. 2, p. 58) has made a detailed structural analysis of the Bergsdalen area, just east of the town of Bergen. Kvale has distinguished two nappes here. The lineation strikes in an east-southeasterly direction and the main direction of thrust lay between east and southeast.

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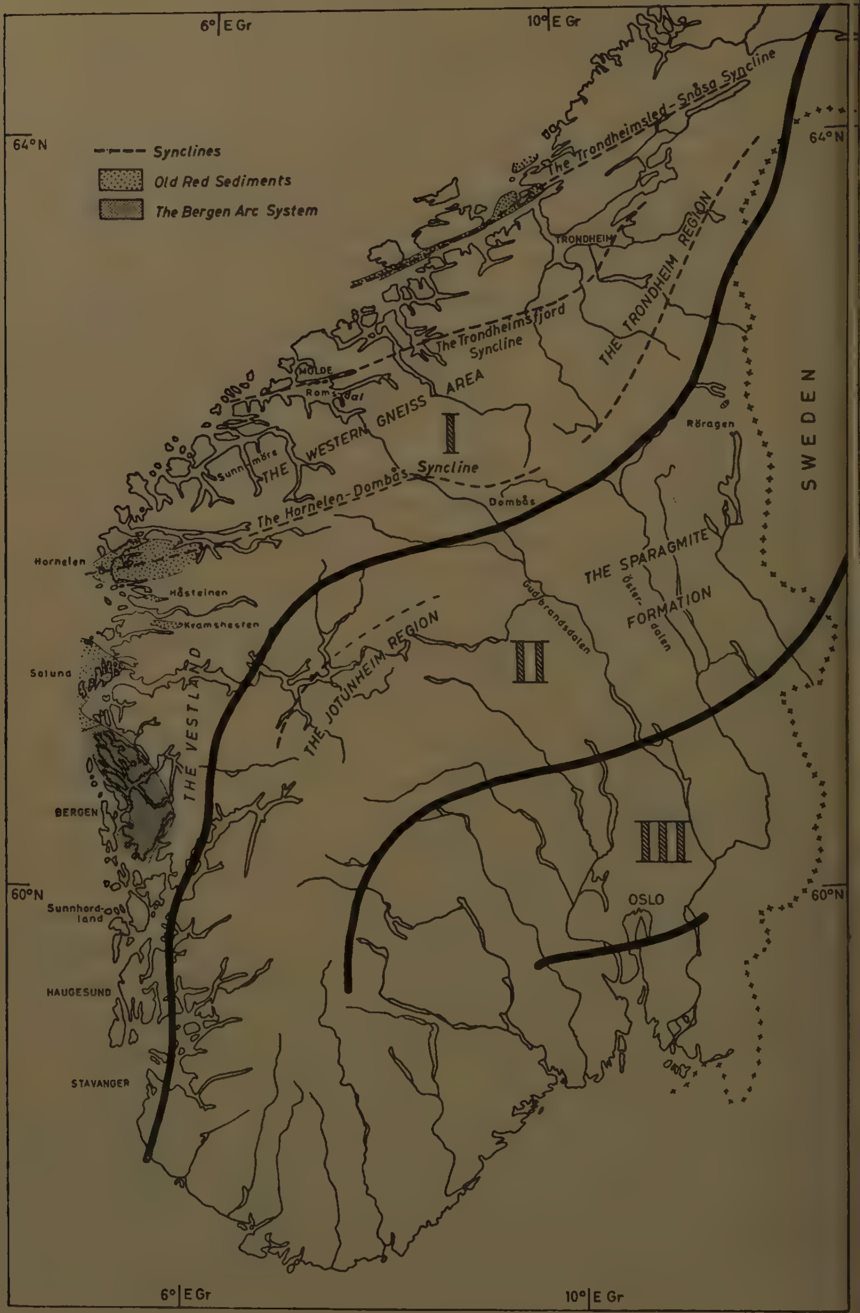
6° E Gr
10° E Gr
64° N
60° N
- - - Synclines
▨ Old Red Sediments
▨ The Bergen Arc System
The Trondheimsled-Snåsa Syncline
TRONDHEIM
The Trondheimsfjord Syncline
THE TRONDHEIM REGION
MOLDE
Romsdal
THE WESTERN GNEISS AREA
I
Sunnmøre
The Hornelen-Dombås Syncline
Dombås
Røragen
SWEDEN
Hornelen
Håsteinen
Kvamshesten
Solund
THE VESTLAND
THE JOTUNHEIM REGION
II
Gudbrandsdalen
THE SPARAGMITE FORMATION
Øster-dalen
III
OSLO
BERGEN
Sunnhord-land
HAUGESUND
STAVANGER

The relationship of the Svalbardian phase of orogeny (VOGT 1928, p. 113) to this view of the geological evolution of the Trondheim and Vestlandet regions, is a question of prime importance. The Devonian synclinal area of Vestlandet undoubtedly took on its present character during a very late phase of folding. The same applies to the Downtonian — Devonian of the Trondheimsled district.

It is an open question how deeply the Svalbardian phase affected the Western Gneiss area. Tectonic investigations on the boundary areas of the Devonian regions will probably yield valuable information regarding this problem. Cand. mag. INGE BRYHNI, who is taking part in the investigations on the Devonian synclinal area of Vestlandet mentioned above, has carried out a very interesting structural analysis of the region lying between the Devonian of Hornelen and Håsteinen. The direction of strike and lineation is predominantly westnorthwesterly here, a result which implies a phase of folding in an arcuate mountain range, and a phase which is older than that of the Svalbardian folding represented by the Devonian synclines. Bryhni's investigations are not yet completed.

I should also like to draw attention to my discussion of the westsouthwesterly fold system in Central Norway (HERNES 1956 c). This structural line has such a constant and widespread character in that area that it is difficult to assume that the Svalbardian folding alone is responsible. I might mention in this connection, too, that H. CARSTENS (1955) assumes that the Snåsa syncline was formed quite early in the Caledonian orogeny.

The Bergen arcs have a main N — S trend and they thus fit quite naturally with my concept of an arcuate Caledonian mountain chain. With their infolded Cambro-Silurian schists these same arcs are so profound in character that it is difficult to imagine that they are due solely to the Svalbardian folding. The Devonian rocks in the most northerly part of the Bergen arcs also appear to be younger than the main phase of formation of the arcs.

Fig. 1. Main Caledonian tectonical zones.

I: Rocks intensely folded during the Caledonian orogeny. Overlying Caledonian nappes to some extent preserved.

II: Rocks thrust during the Caledonian orogeny, the pre-Eocambrian basement mainly unaltered.

III: Rocks folded during the Caledonian orogeny, the pre-Eocambrian basement unaltered.

The Jotunheim Region and the Sparagmite Formation.

The relationship of the Jotunheim region to the arcuate Caledonian mountain range described above, is an important question. Following my concept the region occupies a less central position in the mountain chain than the Trondheim region and Sunnhordland, and a better parallel can be drawn with the Sparagmite formation.

In VOGT's interesting papers on the structure of the Caledonides, a syncline is shown passing through the eastern part of the Trondheim region and continuing southward via the Jotunheim region to Sunnhordland (1946, 1954 a, 1954 b). Vogt does not, however, mean that the transition between the Trondheim region and the Jotunheim region is rectilinear and marks it accordingly, *vide* his last map in particular (1954 b, fig. 1, p. 2). An anticline is also indicated on this map crossing the syncline at the transition point of the regions. This makes it clear that the connection between the two regions is not of a direct and radical type.

Vogt draws a further parallel between the gabbros of the Jotunheim and the gabbros of the eastern part of the Trondheim region, e. g. the Fongen gabbro, since, among other points, he stresses that they occur in the same syncline (VOGT 1954 a, p. 106), and in such a way that we have had, in the syncline itself, extensive break-throughs down to an underlying gabbro substratum. Most geologists today, when considering the great nappes of the Jotunheim region, would probably assent to the view that these have been thrust forward, not molten but as already solidified masses of rock, in the main from the northwest towards the southeast, and to this extent form a foreign element in the syncline.

Let us now consider the distribution of our pyrites deposits. Reference to S. FOSLIE's map of ore deposits in Southern Norway (1925) reveals the well-known feature that the area between the Trondheim region and Sunnhordland is practically sterile from a pyrites geologist's point of view. On the other hand the bordering districts, the Trondheim region and the Sunnhordland area, are characterised precisely by the multitude of their pyrites occurrences. We have here a direct connection between the distribution of the Bymark—Støren group and the presence of intrusive gabbros on the one hand and our pyrites occurrences on the other.

A study of the lineation yields an interesting picture. According to KVALE (1953, map fig. 1, p. 54), the lineation in the extensive nappes of the Jotunheim region strikes approximately northwest, the same direction that we find within the Sparagmite formation also. Within the Trondheim region on the other hand the lineation strikes more or less eastnortheast to northeast, in other words at almost 90° to the Jotunheim lineation. There appears here to be a direct connection between the strike of the lineation and the geological structure of the mountain chain; a northwesterly strike in areas characterised by nappes, the northeasterly strike in areas of folding structure.

The Jotunheim region, with its nappes overlying pre-Eocambrian rocks, with possible pre-Eocambrian rocks along its northwestern side, is markedly different, from a regional geology point of view, from the Trondheim region with its folding structure and its complicated boundary on the northwest. The formation of the Jotun fosse itself is supposed by T. STRAND (1951, p. 36) to belong to the Svalbardian phase of orogeny.

If we do not maintain the traditional view of the mountain chain, that the Jotunheim region continues directly over into the Trondheim region, it is natural to seek a continuation of the Jotunheim region in the Sparagmite formation.

In my opinion there is a striking similarity between the Jotunheim region and the Sparagmite formation. In both areas we are dealing with extensive nappes overlying pre-Eocambrian rocks, the lineation strikes in the same direction, and both areas lie for the most part outside the zone of intrusives and of ore deposits of the mountain chain.

Regarding the differences in the petrography of the two areas, there has scarcely been any deposition of Eocambrian sparagmite in the most western part of the Jotunheim region and southwards. Furthermore, the petrographic differences can be explained by the way in which the present land surface cuts the nappes. Jotunheim rock types found in the Østerdal area indicate that the Jotunheim nappes previously had a much greater extent than we find is the case today (P. HOLMSEN & CHR. OFTEDAL 1956). In the Gudbrandsdal area the rock complexes are in part found to lie horizontal, so that their extent depends in high degree upon the present-day surface topography.

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According to this view of the Caledonian mountain chain, we are dealing with a zone which extends from the Trondheim region over the Devonian synclinal area of Vestlandet to the Sunnhordland area, comprising rock complexes intensely folded during the Caledonian orogeny, a zone which has also to some extent preserved overlying Caledonian nappes. The Jotunheim region and the Sparagmite formation form a less central zone with Caledonian nappes covering little or not altered pre-Eocambrian rocks.

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BLOKK- OG STEINTELLINGER I SOLØR

Stone Countings in Quaternary Deposits in Solør, Southern Norway

Av

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Abstract. Investigations have been carried out on the boulder and stone content of some Quaternary deposits, mainly glacial, in Solør, Southern Norway, as to the ratio between local and foreign material. It was found that the ground moraine usually contains 80 % local material (Archain rocks) and 20 % foreign material (rocks of the Eocambrian formation), the latter supposed to have been transported at least 20—30 km. It was further on found that the content of both foreign material and rounded material decreased with increasing diameter of investigated stones. In contrast to the basal till, the superglacial till might have a content of 80 % foreign material. The superglacial till usually has a greater content of rounded material than has the basal till. In eskers the content of foreign material may rise to above 50 %. It is emphasized, when making similiar investigations, to deal with a great number of size-groups, the result other ways being incorrect.

Innledning.

I det følgende fremlegges resultatet av en del stein- og blokktellinger foretatt i Solør. Undersøkelser ble særlig foretatt av materialet i det vanlige morenedekket, men også enkelte andre typer avsetninger ble betraktet.

Formålet for undersøkelsene var særlig å finne forholdet mellom lokalt og fjerntransportert materiale, men også å undersøke variasjonene i materialets form. Under arbeidets gang viste det seg også tydelig at størrelsen av det undersøkte materiale spilte en avgjørende rolle for resultatets pålitelighet.

Undersøkelsene ble foretatt ved at bergartmateriale ble uttatt direkte fra grustak eller skjæring; i sjeldnere tilfelle ble materiale tatt fra overflaten av morenedekket etterat vegetasjonsdekket var fjernet eller ved gravning. Undersøkelse av blokker (d $>$ 20 cm) ble vanligvis foretatt på materiale som lå igjen i bunnen av grustak.

På grunn av formålet for undersøkelsene ble bergartene kun delt på to store grupper, nemlig grunnfjellsbergarter (lokalt materiale) og sparagmittbergarter med kvartsitt (fjerntransportert materiale). Vanligvis ble bare materiale i fraksjonene 2-5-10-20 cm (dvs. stein) undersøkt, bare i et par tilfelle ble blokker tatt i betraktning. For øvrig vil fraksjonene fremgå av tabellene. I tillegg til undersøkelsene over bergartene fordelt på fraksjonene, ble i enkelte tilfelle også stein- og blokkene gruppert i rundet, kantrundet og kantet materiale. Dette er en temmelig subjektiv gruppering, men skulle likevel gi et inntrykk av materialets form.

Undersøkelsene er ikke av det omfang at man kan trekke så svært mange slutninger av dem. En rekke nærliggende og interessante problemer er derfor ikke berørt. Interesserte henvises til avhandlinger av LUNDQVIST (1935) og LÅG (1948).

Til orientering skal nevnes at i det undersøkte området av Solør (kartblad Nordre Solør) består undergrunnen av grunnfjellsbergarter. De mest utbredte bergarter er granitt og gneiser; hyperitt og dioritt er relativt vanlige; kvartsitt forekommer, men synes å være meget sjelden. Det løse dekket består av hav- og elveavsetninger i de større dalførene. Ellers består løsavsetningene alt overveiende av sandholdig morene. For vurdering av det transporterte materiale i løsavsetningene kan nevnes at avstanden fra de undersøkte lokalitetene i grunnfjellsområdet nord til strøkene med sparagmitt gjennomgående er minimum 20—30 km.

Undersøkelse av stein- og blokkinnholdet i morenavsetninger.

Resultatet av stein- og blokktellinger i vanlig bunnmorene vil fremgå av tabell 1. I det følgende skal det knyttes en del bemerkninger til forholdene ved de forskjellige lokaliteter.

Ved Vestby (vest for Glomma, Våler herred) ble materialet i et grustak i vanlig bunnmorene undersøkt. Resultatet sees av tabell 1 og fig. 1. Av grunnfjellsbergarter dominerte granitt og gneis; dioritt og hyperitt forekom. I gruppen sparagmitt-kvartsitt dominerte kvartssandstein og finkornige, lyse sparagmitter.

Som det sees øker grunnfjellsbergartenes andel fra 62 % i fraksjonen 2—5 cm til 97,5 % i fraksjonen 50—100 cm. I samme interval

Tabell 1. *Resultatet av stein- og blokktellinger i morenedekket i Solør. De oppførte verdier i fraksjonsrubrikkene gjelder den prosentvise forekomst av bergartene innen hver fraksjon (gr.fj. = grunnfjellsbergarter, sp. = sparagmitt og kvartsitt). De oppførte verdier i formrubrikkene gjelder den prosentvise fordeling av bergartene fra alle fraksjoner på gruppene R = rundet, KR = kantrundet og K = kantet materiale.*

Lokalitet	m.o.h.	Antall stein tellet	Berg-art	Fraksjoner i cm					Alle frak-sjoner	Form		
				2–5	5–10	10–20	20–50	50–100		R	KR	K
Vestby	230	438	gr.fj.	62	80	86	91	97.5	79	0	20	80
			sp.	38	20	14	9	2.5	21	50	37	13
Knappkoimyra	230	309	gr.fj.	74	73	83		96.5	78			
			sp.	26	27	17		3.5	22			
Bronkeberget .	420	300	gr.fj.	68	64	91			68	0	5	95
			sp.	32	36	9			32	5	40	55
Skydomstjern .	320	120	gr.fj.	59					59	0	3	97
			sp.	41					41	2	31	67
S. Fløgen	300	240	gr.fj.		66				66			
			sp.		34				34			
Mellem	230	117	gr.fj.		50.5				50.5			
			sp.		49.5				49.5			
Jerdrumsæter	480	106	gr.fj.	67					67			
			sp.	33					33			
Svevad	330	150	gr.fj.			77			77			
			sp.			23			23			

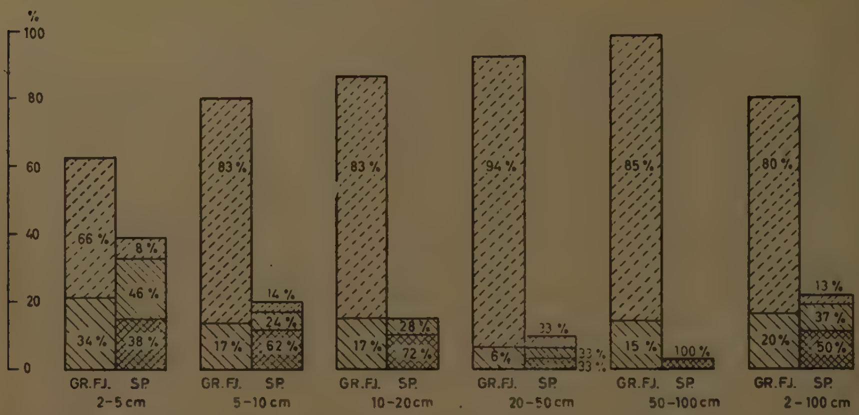

Fig. 1. Resultatet av stein- og blokktellinger i morenedekket ved Vestby i Våler. Tegnforklaring: gr.fj. = grunnfjellsbergarter, sp. = sparagmittbergarter og kvartsitt. Stiplet skravur betegner kantet materiale, heltrukken skravur betegner kantrundet materiale og krysskravur rundet materiale.

minker sparagmitten fra 38 % til 2,5 %. Gjennomsnitt for alle fraksjoner gir 79 % grunnfjellsbergarter og 21 % sparagmittbergarter.

Av fig. 1 sees videre at blant grunnfjellsbergartene forekom ikke rundet materiale i det hele tatt, mens det var relativt hyppig blant sparagmitten. Dette forårsaker følgelig at prosent rundet materiale også avtar fra minste til største fraksjon, nemlig fra 15 % til 2,5 %.

Resultatet av tellingene ved Knappkoimyra, ca. 1 km nordenfor Vestby, sees av tabell 1 å stemme meget godt overens med forholdene ved Vestby, særlig når man betrakter forholdet mellom grunnfjells- og sparagmittbergarter alle fraksjoner tatt under ett.

Tellingene ved Vestby og Knappkoimyra er sannsynligvis de mest representative av de foretatte, dels fordi et relativt stort antall stein og blokker er undersøkt, dels fordi undersøkelsene dekker hele intervalet fra 2 til 100 cm.

Resultatet av de øvrige seks tellinger som ble foretatt i bunnmorenedekket viser at ved alle de tilsvarende lokaliteter ligger sparagmittprosenten høyere enn ved Vestby-Knappkoimyra. Dette kan ikke bare skyldes at mindre fraksjoner ble undersøkt. Det er også tydelig at avstanden til anstående sparagmitt ikke kan ha nevneverdig å si, fordi lokalitetene ligger dels lenger fra (Skydomstjern), dels nærmere (Mellem, Svevad) enn Vestby. Det ser heller ikke ut som høyden over havet spiller noen rolle. Det er imidlertid mulig at man ved nøyere undersøkelser av selve avsetningene ville ha funnet en forklaring på forskjellen.

Det skal her også pekes på den omstendighet at ved Vestby dominerte rundet materiale i gruppen sparagmitt, mens det var minst av kantet. Ved Bronkeberget og Skydomstjern var det omvendt. Ved disse lokalitetene hadde det imidlertid vært rimelig å tro at rundet materiale skulle ha dominert p.g.a. de mindre fraksjoner. Forklaringen på dette må åpenbart søkes i forskjell i transportmåte uten at en kan si noe nærmere om det.

Det er i det foregående kun omtalt tellinger i vanlig bunnmorene. I det følgende skal det gis resultatet av tellinger i enkelte spesielle typer morene, og det henvises til tabell 2 hvor resultatet er satt opp.

Ved Holtsjøen, omtrent midt mellom Glomma og Kynna (Våler herred) ble det foretatt tellinger i en meget markert, vel 10 m høy morenerygg. En telling ble foretatt oppå ryggen, den andre i en skjæring 6 m under overflaten. Som det sees av tabellen er forskjellen i bergartssammensetningen øverst og nederst liten, men det kan nesten se ut som om grunnfjellsbergarter (lokalt materiale) dominerer i toppen. Det er også verdt å legge merke til at rundet materiale er meget sparsomt, totalt for begge tellinger under 1 %. Den tilsvarede verdi for tellingen i bunnmorenen ved Vestby var vel 10 %.

Et helt annet bilde gir tellingene ved Slobekken (mellom Svarttjern og N. Fløgen) ca. 6 km nordøst for Holtesjøen. Som tabell 2 og fig. 2 viser ble det foretatt to tellinger i morenedekket på samme sted, den ene i overflatemorenen, den andre i bunnmorenen. Som det sees dominerer sparagmittbergarter med 79 % i overflatemorenen, mens det i bunnmorenen kun er 21 % sparagmitt. Videre sees at rundet materiale ikke finnes i bunnmorenen, mens 14 % av sparagmittmateriale i overflatemorenen er rundet. Undersøkelsene viser meget tydelig at det er en markert forskjell både i bergartsammensetning og materialets form i overflatemorenen i forhold til bunnmorenen. Dette resultat bestyrkes av en telling ved Vestgårdsætrene, på vestsiden av Glomma ved Våler, hvor en undersøkelse ble foretatt i overflatemorenen som her viste seg å ha 49 % sparagmittbergarter. En har også fått det inntrykk i sin alminnelighet at det fjerntransporterte materiale avtar med dybden.

Av undersøkelser i morene skal til slutt nevnes en telling i en leirholdig moreneavsetning ved Bronka (Omtalt av G. Holmsen, Tabell 2. *Resultatet av steintellinger i forskjellige typer morener i Solør. Forklaring, se tabell 1.*

Lokalitet	m.o.h.	Antall stein tellet	Bergart	Fraksjon		Alle fraksjoner	Form		
				2–5 cm	5–10 cm		R	KR	K
Holtsjøryggen, overflaten	300	104	gr.fj.	82	100	85	0	9	91
			sp.	18	0	15	0	60	40
Holtsjøryggen, bunnen.............	300	109	gr.fj.	78	77	78	0	12	88
			sp.	22	23	22	8	42	50
Slobekken, overflatemorene	350	227	gr.fj.	19	35	21	0	11	89
			sp.	81	65	79	14	52	34
Slobekken, bunnmorene............	350	80	gr.fj.	80	74	79	0	8	92
			sp.	20	26	21	0	18	82
Vestgårdsæter	270	118	gr.fj.	51		51	2	30	68
			sp.	49		49	28	55	17
Bronka	320	63	gr.fj.	44		44	0	0	100
			sp.	56		56	17	20	63

1954, p. 40). Denne morenen atskiller seg fra den vanlige bunnmorene i Solør ved at av materiale mindre enn 2 mm er hele 15 % mindre enn 2 μ, mens leire så å si ikke finnes i morenedekket forøvrig. Tellingen ga som resultat 56 % sparagmittbergarter, en meget høy verdi, fraksjonen tatt i betraktning.

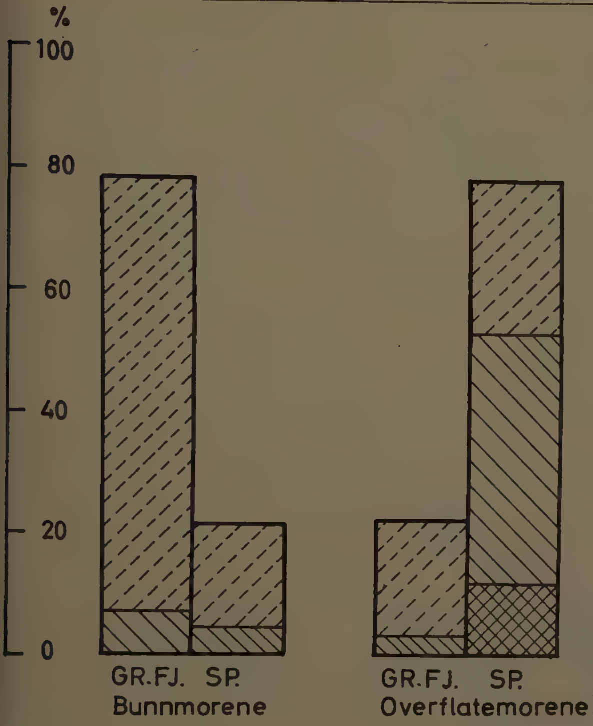

Fig. 2. Resultatet av undersøkelser av materialet i fraksjonen 2—10 cm i morenen ved Slobekken i Våler.

Det skal her nevnes et forhold som ikke fremgår av tellingene i morenedekket. Det ble på et par steder iakttatt bunnmorene som syntes å inneholde kun bergarter fra undergrunnen på stedet. Dette er tidligere iakttatt og nærmere beskrevet av Låg (1948, p. 25).

Undersøkelse av steininnholdet i delta-, elve- og breelvavsetninger.

Det skal til slutt nevnes resultatet av noen små tellinger i andre avsetninger enn morene (se tabell 3).

I et senglasialt delta ved Teppa (Glommas vestside, rett vest Våler) ble det foretatt en telling i det usorterte topplag og en i det lagdelte materiale et par meter under. Resultatet viser at sparagmittprosenten er relativ stor og at det er liten forskjell i bergartssammensetningen i de to sonene.

Ved Gillerholtmoen, øst for Strætåsen, ble materialet i en liten ås undersøkt. Sparagmittprosenten var her 37.

Tabell 3. *Resultatet av steintellinger i et delta* (*Teppa*) *og i breelvavsetninger i Solør.*

Lokalitet	m.o.h.	Antall stein tellet	Bergart	Fraksjon	
				2–5 cm	5-10 cm
Teppa, usortert...	190	112	gr.fj.	53	
			sp.	47	
Teppa, sortert....	190	94	gr.fj.	57	
			sp.	43	
Gillerholtmoen ...	180	152	gr.fj.		63
			sp.		37
Damsjøen	280	91	gr.fj.		48
			sp.		52
Mortkrakken	285	90	gr.fj.		33
			sp.		67

Ved Kynnsjøen ble en telling foretatt nedenfor Damsjøen i materiale som var elveavsatt, men trolig utvasket fra en ås. Innholdet av sparagmittbergarter var her 52 %. Noe lenger nord, ved Ormsund, ble en telling foretatt i Mortkrakken, en ås som er noe sekundært utplanert av vann. Sparagmittprosenten var her så høy som 67.

Det foreliggende materiale fra breelvavsetninger er noe sparsomt, men det synes klart at innholdet av fjerntransportert materiale (sparagmitt) er høyere enn det som er tilfelle i morenedekket. Det er naturlig å se dette som en følge av at disse åsene er dannet av supraglasialt materiale.

Konklusjon.

På grunnlag av det fremlagte materiale over stein- og blokktellinger i Solør synes det å være mulig å trekke følgende konklusjoner, gjeldende for det undersøkte område.

1. Morenematerialet består, når man tar hensyn til materiale mellom 2 og 100 cm, av nesten 80 % lokalt materiale (grunnfjellsbergarter) og vel 20 % fjerntransportert materiale (sparagmittbergarter; transportlengde minimum 20—30 km).
2. I morenematerialet avtar både prosenten av sparagmittbergarter og prosenten av rundet materiale med stigende kornstørrelse.

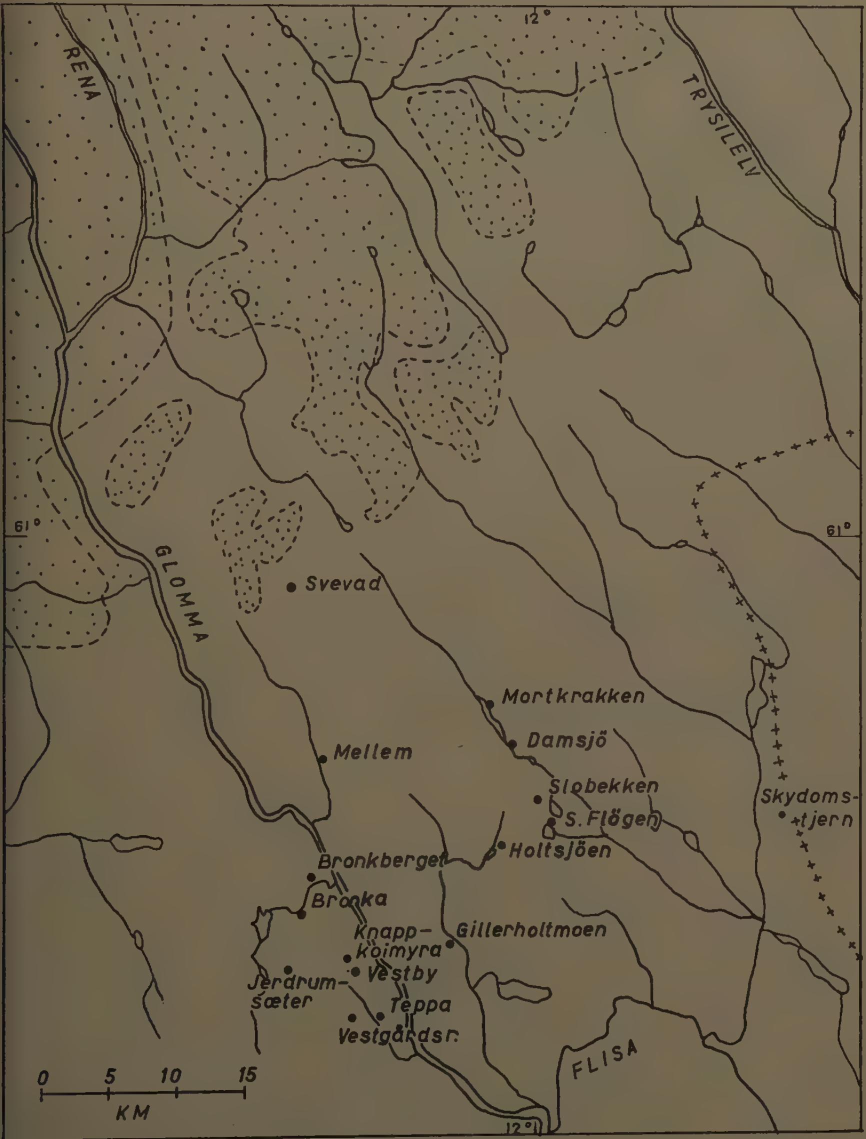

Fig. 3. Kartskisse over det undersøkte området, med inntegnete grenser for sparagmittbergarter i nord.

3. Blant det rundete materiale dominerer fjerntransportert.
4. Der hvor overflatemorene tydelig kan skilles fra den egentlige bunnmorene, kan overflatemorenen ha opptil 80 % fjerntransportert materiale, mens den egentlige bunnmorene på samme lokalitet bare har 20 %.
5. Overflatemorenen har et større innhold av rundet materiale enn bunnmorenen.
6. Breelvavsetninger kan ha opptil tre ganger så stor prosentverdi av fjerntransportert materiale som bunnmorenen.
7. Ved stein- og blokktellinger bør man undersøke flest mulige fraksjoner, da man ellers vil få et uriktig bilde av bergartssammensetningen.

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Trykt august 1957.

JORDTEMPERATUREN I ØST-NORGE

Ground Temperature in Eastern Norway

Av

JOHAN MOUM OG IVAN TH. ROSENQVIST

Abstract. The temperature is registered in a clay deposit near Oslo to a depth of 16 meters throughout the year June 15th, 1955 to June 15th, 1956. It is observed that the annual variations are less than 0.1° C at depths below 8 meters.

For enhver fysikalsk-kjemisk undersøkelse er det av viktighet at man kjenner temperaturen i det miljø man ønsker å studere. Av slike problemer bearbeider vi ved Norges geotekniske institutt forskjellige kjemiske og elektrokjemiske reaksjoner, f. eks. leirenes forvitringsprosesser in situ og korrosjon av stålpeler i jord. Det var derfor av avgjørende betydning å kunne klarlegge hvorledes temperaturforholdene i jorden varierte med dybden og med årstidene. Det viste seg ved gjennomgåelse av litteraturen at ingen hadde utført slike målinger i Norge ned til de dyp vi var interessert i, og heller ikke kunne vi finne opplysninger som kunne anvendes for norske forhold. Rudolf Geiger behandler i «Das Klima der Bodennahen Luftschicht», Braunschveig 1950, jordtemperaturen og temperaturvekslingene med dyp og tid og viser til en rekke tidligere undersøkelser. Hans angivelser er likevel bare av begrenset verdi for oss; for det første er de jordarter som er undersøkt av en vesentlig annen art enn våre øst-norske leirer, for det annet er de klimatiske forhold vesensforskjellige på de steder der undersøkelsene har foregått og hos oss. For det tredje synes det ikke som om undersøkelsene er foretatt ned til større dyp enn ca. 4 meter, mens vi er interessert i temperaturvariasjoner ned til vesentlig større dybder. Det var derfor nødvendig å foreta slike målinger selv for å kunne ha et pålitelig grunnlag til bedømmelse av korrosjonesprosesser og forvitringsproresser. Som målested valgte vi krysset Ringveien/Holmenkolbanen ved Gaustad utenfor Oslo. Dette sted har for det første den fordel at det ligger nær ved vårt laboratorium, for det annet svarer høyden over

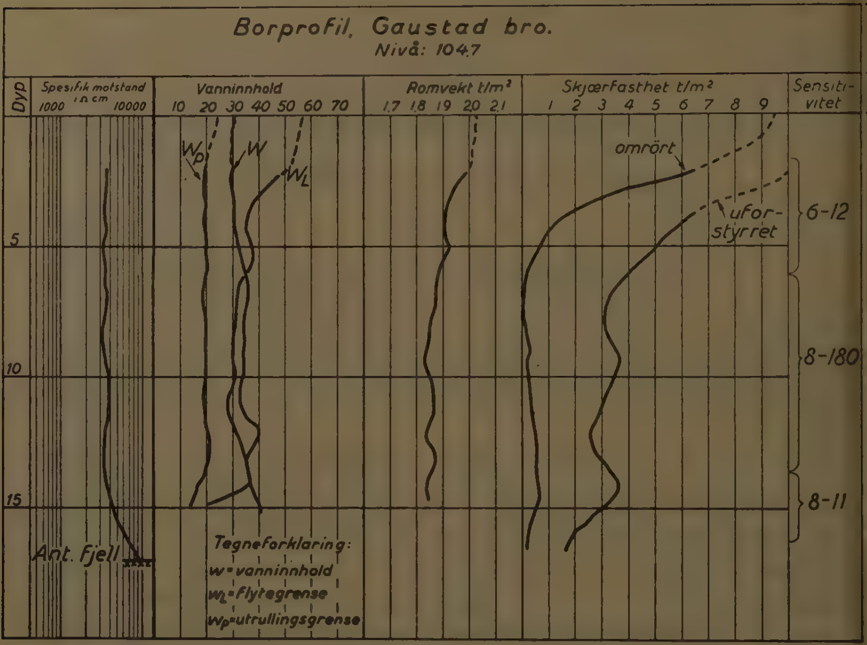


Fig. 1.

havet, 105 meter, bra med gjennomsnittshøyden i Østlandets lavland, for det tredje er det ikke skogbevokset men heller ikke fullstendig trebart og terrenget er passelig kupert, slik at luftsirkulasjonen over overflaten må antas å ha vært av noenlunde gjennomsnittlig størrelse. Til sist skal nevnes at observasjonsstedet ligger i forholdsvis kort avstand fra Meteorologisk Institutt, slik at vi kunne få pålitelige opplysninger om hvorledes temperaturen og snøforholdene har variert på observasjonsstedet. Vi vil hermed få takke Meteorologisk Institutt ved avdelingssjef Werner-Johannesen for den velvillige hjelp de har ytet oss.

Jordarten på angjeldende sted er leire, øverst en vitringsskorpe, under det en relativt normal leire og derunder kvikkleire til fjell. Dybde til fjell var 17 meter (se fig. 1). For å måle temperaturen konstruerte vi et eget instrument bestående av to termistorer 1500 Ohm 4 % pr. C°, hvorav det ene var anbrakt i en kobbersonde som kunne forlenges med forlengelsesrør og drives ned gjennom marken til fjell.

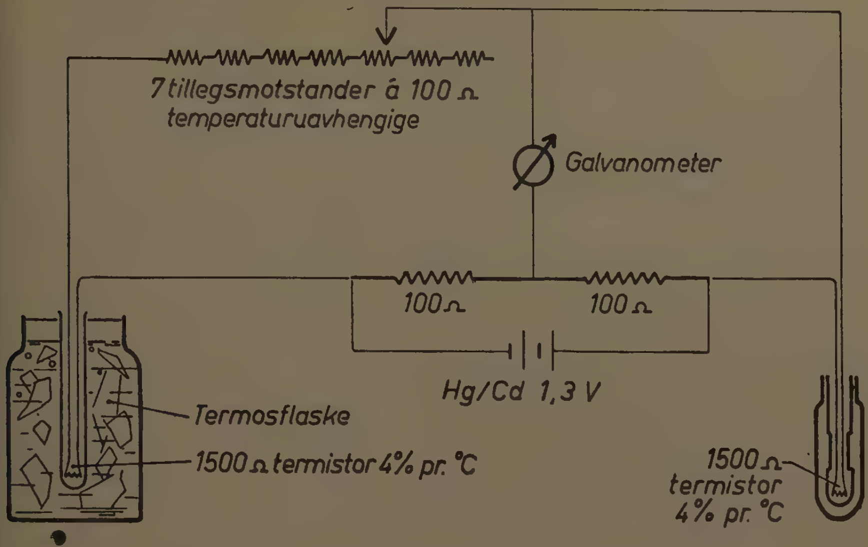


Fig. 2.

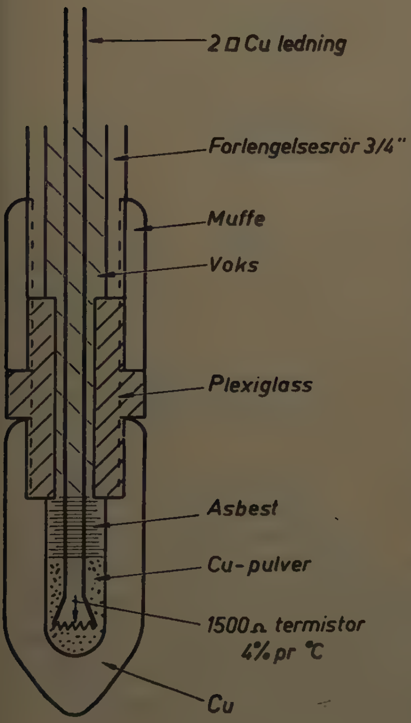


Fig. 3.

Den annen termistor var anbrakt i et reagensglass som sto ned i en termosflaske med is og vann. Fra begge termistorer gikk 2 mm² kobberledninger fram til en fastloddet Wheatstone's bro med tilleggsmotstander. Broen var tilkoplet et kvikksølvkadmium element som strømkilde. Broens assymmetri ble målt med lysflekkgalvanometer med et vanlig bilbatteri som strømkilde. Anordningen kan sees av fig. 2 og fig. 3.

For å ha tilstrekkelig nøyaktighet og følsomhet var det her ikke mulig å anvende broen som O-punktinstrument. Ved de relativt små temperaturvariasjoner som opptrer i et jordprofil gjennom et år, vil et relativt lite sett tilleggsmotstander være tilstrekkelig til å holde asymmetrien innenfor forholdsvis trange grenser. Ved forsøk i laboratoriet viste det seg at vi med det anvendte instrument med letthet kunne registrere temperaturdifferanser av størrelsesorden 1/1000° C. Ved anvendelsen av termistorer står man imidlertid overfor den vanskelighet at de ikke er tilstrekkelig stabile, slik at instrumentet må kalibreres temmelig ofte, og da vi for kalibrering kun hadde en Høpler ultra-termostat til disposisjon, kunne vi av denne grunn ikke kalibrere med større nøyaktighet enn ca. ± 0,02 C°. Hertil kommer systematiske feil i termometeret etc., slik at man må regne med en kalibreringsfeil av størrelse ca. 0,05 C°, hvorfor vi ikke har funnet det riktig å angi jordtemperaturen med større nøyaktighet enn dette. For alle praktiske formål vil også en temperaturangivelse med intervaller på 0,1° C være mer enn tilstrekkelige.

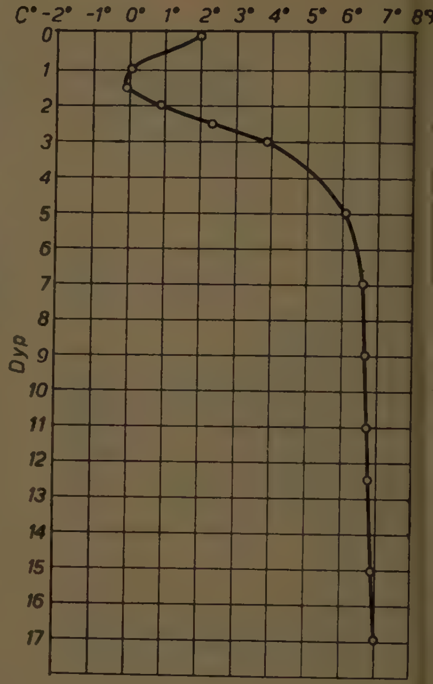
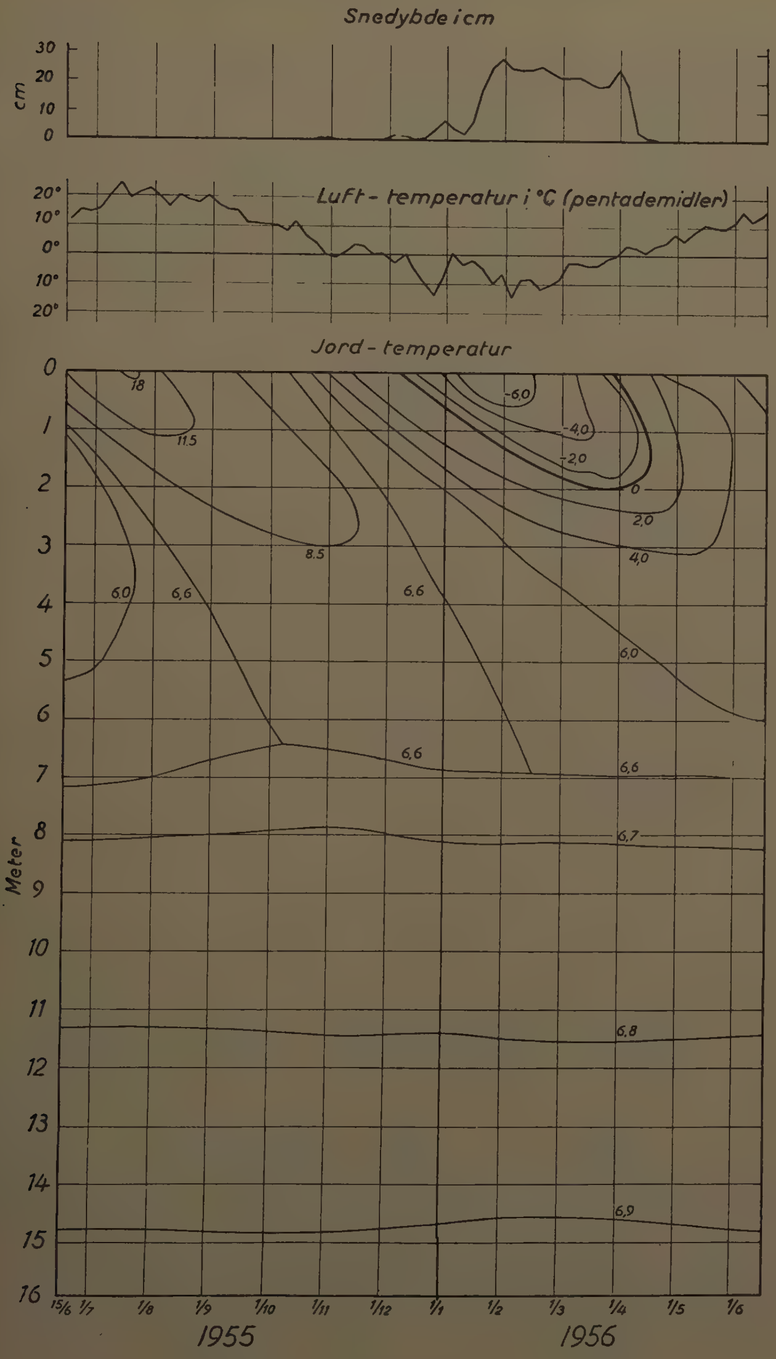


Fig. 4.

Våre målinger ble utført på den måte at «termometeret» ble presset ned gjennom marken ved hjelp av en donkraft og temperaturen avlestes i alminnelighet på hver halvmeter etterat instrumentet var kommet i ro. I de øverste 40 cm ble dessuten temperaturen registrert ved hjelp av kvikksølvtermometer. Målingene ble i alminnelighet foretatt hver 15. i hver måned, av og til litt sjeldnere. Målingene ble startet 15. juni 1955 og fortsatt til 15. juni 1956. For å angi jordtemperaturens variasjon med tid og dybde, kan man benytte seg av flere metoder, f. eks. ved hjelp av såkalte tautochroner, dvs. linjer som angir temperaturforholdenes avhengighet av dybde i bestemte tidsøyeblikk. Vi har også tegnet opp slike tautochromer etter hver observasjonsdag (se fig. 4), men finner at en sammenstilling av slike tautochromer gir et lite oversiktlig bilde, og velger derfor her å angi variasjonene med tid og dybde ved et isotermdiagram, fig. 5.

Bortsett fra et par små uregelmessigheter gir de isotermer som her


Snedybde i cm
cm
30
20
10
0
Luft - temperatur i °C (pentademidler)
20°
10°
0°
10°
20°
Jord - temperatur
Meter
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
18
11.5
8.5
6,0
6,6
6.6
-6,0
-4,0
-2,0
0
2,0
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6,6
6,6
6,7
6,8
6,9
15/6
1/7
1/8
1/9
1/10
1/11
1/12
1/1
1/2
1/3
1/4
1/5
1/6
1955
1956

Fig. 5.

er trykket meget regelmessige kurver gjennom observasjonspunktene. Dersom temperaturen istedenfor å bli bestemt i 1/10°, var blitt angitt i 1/100°, ville imidlertid profilene, særlig de to øverste metere, oppvise en noe mer urolig flate. Som det nå er, gir isotermdiagrammet oss en del viktige opplysninger. For det første ser vi at under et dyp av ca. 8 meter blir ikke årstidsvariasjonene så store som 0,1° C. For det annet øker temperaturen fra dette dyp nedover regelmessig med 1/50° pr. meter. Dersom man fra denne geometriske gradient ekstrapolerer årets gjennomsnittstemperatur opp til markoverflaten, vil man finne en temperatur av ca. 6,4°. Dette er nøyaktig 1° C høyere enn lufttemperaturmidlet ved Meteorologisk Institutt. Vi ser av dette at sommervarmen har kunnet komme inn med et vesentlig høyere bidrag enn vinterkulden. Snødekket fra desember til mars er en bedre isolator enn vegetasjonsdekket i sommermånedene. Videre ser vi at 0°-isotermen går ned til nøyaktig 2 meters dyp på dette sted. Derimot gikk telefrysningen ned til vel 1,70 meter, slik at man hadde 30 cm med underkjølet jord fra en temperatur av ca. -2,1°. Fra -2,1° til 0° var leiren myk ved observasjon 15. mars, til tross for at 0° denne dato først ble funnet i dyp av 2 meter.

Vår konklusjon av de foretatte målinger er at prosesser som fremmes, enten av spesiell høy temperatur eller av temperaturvariasjoner, føsrt og fremst vil finne sted i markdyp ned til 4 meter. Ved større dyp er temperaturen relativt konstant.

SUMMARY

The soil temperature has been registered throughout the year June 15th, 1955 to June 15th, 1956 to a depth of 16 meters in a clay at Gaustad near Oslo.

The geotechnical consistence of the soil is seen from figure 1. The site corresponds to average conditions of the East Norwegian lowland. As an instrument for the determination was used two thermistores 1500 Ohm 4 % per Centigrade. One was placed in a copper sound which could be pressed down to solid rock by means of elongation tubes. The other thermistore was placed in melting ice. As registration instrument a soldered Wheatstone's Bridge with additional resistance was used. The asymmetry of the bridge differences of 1/1000° C. The soil temperature, however, is only given in inter-

vals of 0,1° C. The isotherms are seen from figure 5. Below the depths of 8 meters, the annual variations are less than 0,1° C and the temperature increases by 1/50 of a degree per meter. From 1,70 meter to 2 meters, undercooling was observed between the freezing point and -2,1° C on the 15th of March, 1956.

Manuskript mottatt 7. desember 1956.

Trykt august 1957.

NOTISER

Ra-moräner vid Helgelandskusten?

Av

HARALD SVENSSON

(Geografiska Institutionen Lund.)

Större riktningsbestämda moränförekomster äro för Tröndelag kända genom undersökningar av bl. a. Holtedahl (1928) och Undås (1942). I Troms har bl. a. Grönlie (sammanfattat 1940) undersökt en väl utvecklad moränserie. Dessa forskare äro av den åsikten, att moräner vid Trondheimsfjorden respektive i Tromsö-Lyngen-området kunna parallelliseras med ra-erna i Syd-Norge.

Om nämnda forskares antagande är korrekt, bör det med den brutenhet, som den nordnorska kusten besitter, finnas ännu andra, hittills okända moräner av motsvarande ålder och ursprung mellan de angivna områdena. Detta är en av författarens arbetshypoteser i de pågående glacialgeologiska undersökningarna vid Helgelands och Nordtröndelags kust.

I form av detta meddelande skall här en observation från sydligaste Helgeland i korthet omnämnas.

Under rekognoseringar sommaren 1954 påträffade jag på östra sluttningen av Heilhornmassivet (topografiska kartbladet H 19 Leka, geologiska generalkartet Vega) en imponerande moränvall av nära fem kilometers obruten längd (fig. 1). I branta sluttningar blir den ibland diffus men framstår då såsom en tydlig morängräns (nedre vänstra delen av fig. 2). Norr om Botnet uppträder en annan moränvall, som av allt att döma bildar fortsättning på Heilhornmoränen.

På det geologiska generalkartet Vega (Rekstad 1917) är moränförekomster angivna i Horndalen och vid Lysfjord. Däremot saknas uppgift, såväl på kartan som i dess beskrivning, om den här behandlade moränvallen.

På grund av avsaknaden av vegetation inom sin övre del, vilken jämte västsluttningen är starkt utsatt för vindar, avtecknar sig moränvallen distinkt på flygfoto (fig. 2). (En flygfotografering över en del av området möjliggjordes 1955 genom bidrag från Statens naturvetenskapliga forskningsråd.)

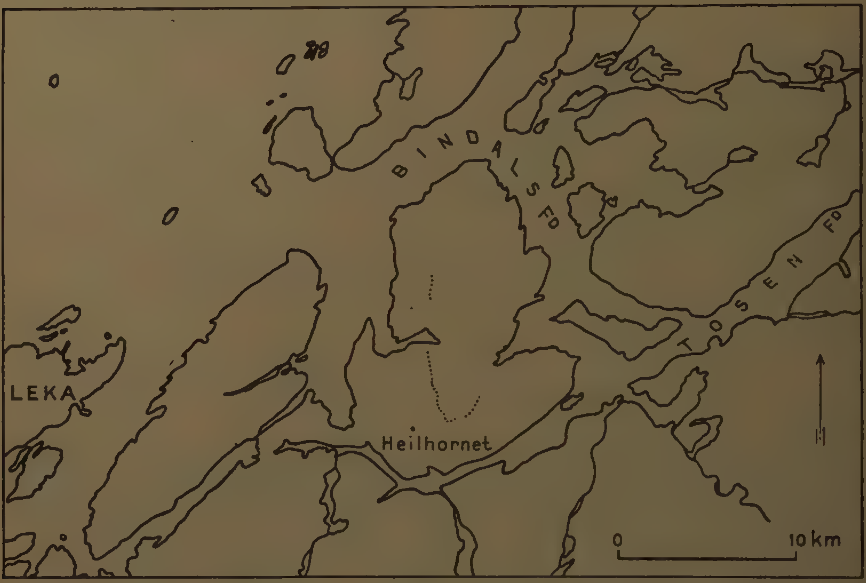

Fig. 1. Området kring yttre Tosenfjorden. Den prickade linjen anger det behandlade moränstråket.

Moränvallens mäktighet, vilken varierar med berggrundsytans topografi, kan ej exakt angivas beroende på att materialet avsatts i en sluttning. Vid bäckgenombrottet mellan Kuglen och Lillehornet (fig. 2) är vallen emellertid genomskuren till 16 meters djup ned till fast berg; vid Amundstj., som är uppdämd av moränen, har en 25 meter djup passage eroderats.

Höjden växlar för olika delar av moränvallen. Inom det avsnitt, vilket återgives på fig. 2, varierar moränens höjd mellan 510 och 475 m ö.h. Framför Amundstj. ligger överdelen av vallen 385—390 m ö.h.

Det i moränen ingående materialet är av utpräglat lokalt ursprung med en ansamling av block på västra sidan av moränvallen (distalsidan). Sekundärt sker även en anrikning utav block på vallens krön genom deflationen (fig. 3).

En inom några delar av moränen svagt framträdande, dubbel ryggform låter antyda en upprepad hopskjutning av materialet.

Heilhornmoränen har avsatts under inflytande av ett östligt istryck. Moränvallen buktar sålunda följsamt in i sluttningens större och mindre konkaviteter (fig. 3).

Moränen måste sättas i samband med under avsmältningstiden i Tosenfjorden befintliga ismassor, vilka under inflytande av skärpta klimatiska förhållanden aktiverats. Den till moränen svarande

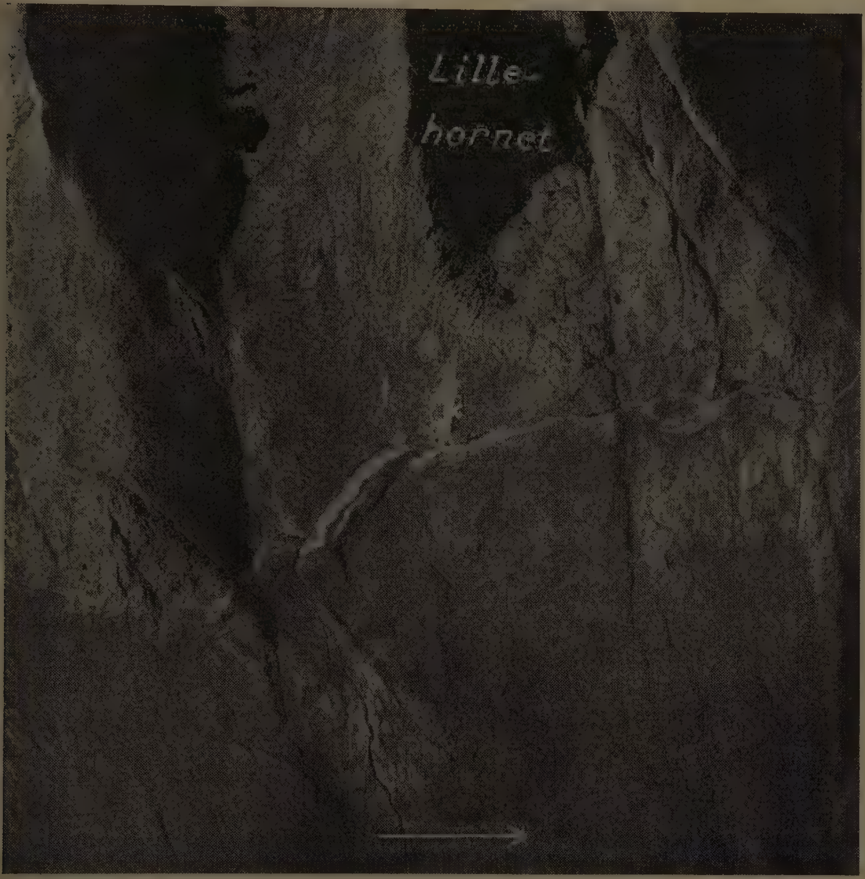

Fig. 2. Parti av Heilhornmassivets östra sluttning med Heilhornmoränens norra del. Flygfoto från 4000 meters höjd.

fria isranden, härrörande från fjordglaciärerna kan ha nått ut på strandflaten i väster.

Heilhornmoränen utgör inget yttersta israndläge, eftersom såväl i högre belägna delar av Heilhornmassivet som på strandflaten isskuring iakttagits. Isskuring förekommer sålunda helt ut på Sklinna.

Av intresse har varit att undersöka om andra moränackumulationer av samma slag och omfattning som den beskrivna förekomma på Heilhornmassivets östra sida, särskilt då sådana som äro belägna på lägre nivå och avsatta under inflytande av en senare Tosenglaciär. Sådana moräner, vilka kunnat tagas såsom indicier på en senare, markant klimatförsämring, ha ej påträffats. Det normala täcket

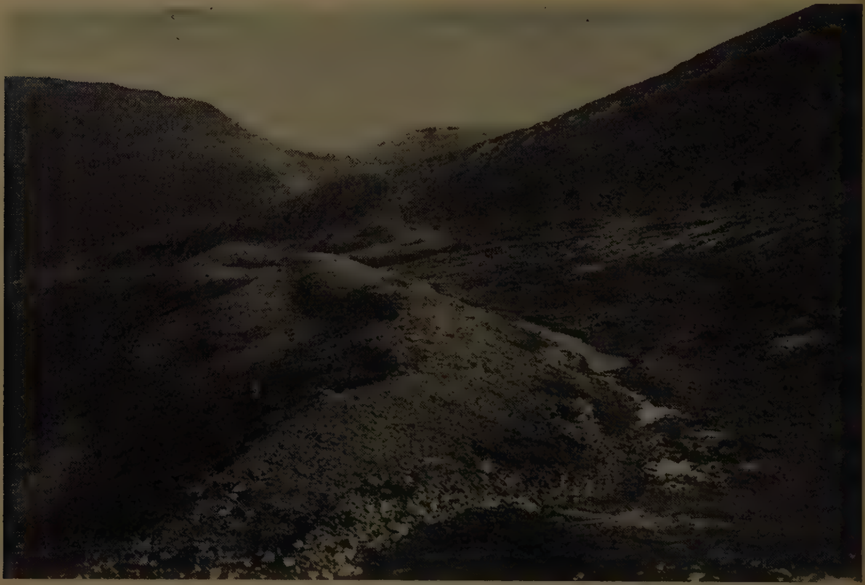

Fig. 3. Moränvallen vid ingången till passet mellan Kuglen och Lillehornet. Bilden tagen i sydostlig riktning från den med ett kors utmärkta punkten på fig. 2.

av ablationsmorän på sluttningen nedanför Heilhornmoränen antyder också en störningsfri avsmältning, sedan moränen ackumulerats.

Ett bestämt ställningstagande ifråga om konnektion av moränlinjer vid Helgelandskusten med Tautra- och Tromsö-Lyngentrinnet är ej möjligt, förrän observationsmaterialet rörande andra iakttagna moräner i området slutgiltigt sammanställts. Konstateras kan dock att moräner förekomma och att i dessa en klimatförsämring finns registrerad.

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Manuskript mottatt 11. desember 1956.

Trykt august 1957.

On the orbicular structure in the norite of Romsaas, Norway

By

HARALD CARSTENS

The orbicular norite of Romsaas has been described by C. BUGGE (1906) and J. H. L. VOGT (1921). Reference to earlier literature on the subject is found in these papers.

It is the purpose of the present note to show that although the orbicular structure proper is mainly localized to the border of the norite massif, embryonic orbs are developed in the normal quartz-norite of Romsaas.

Two varieties of the orbicular norite, with large and small orbs respectively, were distinguished by Bugge.

The great orbs, having a diameter of 4—9 cm (averagely about 5 cm), consist almost exclusively of hypersthene, *radially arranged.* A concentric structure may, however, be present near the margin in the largest orbs. A thin shell of biotite and/or hornblende separates the orbs from the groundmass which consists of plagioclase and quartz.

The small orbs of the other variety (diameter 2 cm), differ from the greater orbs by the absence of the outer biotite/hornblende shell. The delimination of the orbs from the groundmass is therefore not so sharp as in the former case.

Bugge pointed out that all gradations between the two varieties exist. The present writer noticed during a short visit to Romsaas that the diameter of the orbs sometimes did not exced 2—5 mm. The orbicular structure is not, however, so readily noted in these norites.

Considering thin sections of the ordinary quartz-norite it is often observed that the hypersthene crystals have accumulated in groups (the texture is synneusis according to Vogt). And we are at once struck by the fact that in the individual groups, the radial arrangement of the hypersthene is still commonly a characteristic feature.

Thus, it has been proved that *a continuous transition exists between the structure of the normal norite and the orbicular norite.*

What fastors controlled the orientation of the hypersthene in the norite of Romsaas? It may be worth while to study a contrasted type of preferred orientation of hypersthene crystals in some other Norwegian norites, before any attempt is made to answer this question. In the augite-bearing norites of Raana and Skjaekerdal the hypersthene, elongated parallel to the c-axis, shows a planar orientation, and sometimes also a tendency to linear structure has been observed. The coexisting monoclinic pyroxene, on the other hand, forms stubby, unoriented crystals. Now and then they may attain great sizes, containing inclusions of hypersthene, and a pseudo-porphyritic texture is produced.

It seems likely to assume that the orienting tendency of the hypersthene in the norites, whether the texture be spheroidal or parallel, is due to the early separation of hypersthene from a magma in movement. (It is suggested that strong turbulent motion may be favourable for the development of a spheroidal texture.)

Statens Råstofflaboratorium, March 1957.

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Manuscript received April 4, 1957.

Printed August 1957.

Vannboring i Leikanger, Indre Sogn.

AV

FINN J. SKJERLIE

Våren 1954 ble det foretatt to vannboringer i Leikanger, Indre Sogn. Den ene ble utført for hotelleier Gustav Lie på Leikanger Hotells grunn. Resultatet ble over all forventning. Vannet er av førsteklasses kvalitet, og temperaturen ligger på ca. 5° C. hele året. Prøvepumpingen ga 2000 liter pr. time. Kartet (fig. 1) viser borhullets lokalitet. Borhullet ligger ca. 50 m fra sjøen, og ca. 3 m o.h. Den vannførende sone ble påtruffet 15—20 m under havets overflate. Det ble først boret gjennom en sone av finkornet granittisk gneis, hvoretter en traff på glimmerskifer. Et stykke ned i glimmerskiferen var det at vannåren ble funnet. Borhullet var av artesisk karakter.

Den annen brønnboring ble utført for Jon Husabø like ved hjørnet på huset hans (fig. 1). Denne har forfatteren ikke fått anledning til å se, men av innsamlete opplysninger fremgår det at den er en parallell til borhullet ved Leikanger Hotell. Også på Husabø boret en først gjennom en gneissone, hvoretter en traff på glimmerskifer. Trykket

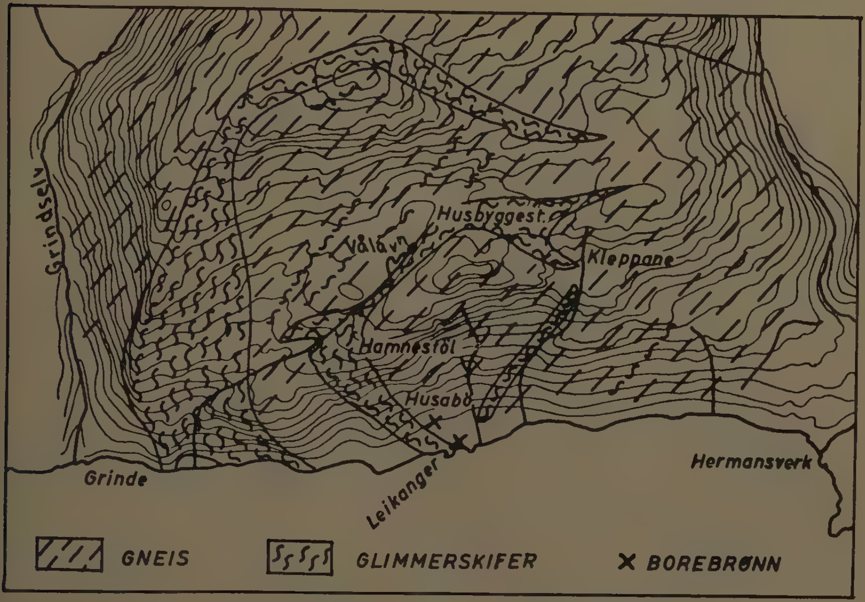

Fig. 1. Geologisk kart over Leikangerområdet.

er imidlertid betraktelig større her enn i borhullet ved Leikanger Hotell. Hullet har vanlig diameter (4 tommer), men er blitt strupt inn til 1 tomme. Det er et meget kraftig trykk i 1. etasje, over full kjellerhøyde.

Fra et geologisk synspunkt er resultatet meget interessant. For det første har både gneisen og den underliggende glimmerskifer en meget lav permeabilitet, og bergartene i seg selv er derfor ikke vannførende. For det andre er trykket så stort at sjøvannet ikke trenger inn i borhullet ved Leikanger Hotell og ødelegger drikkevannets kvalitet, slik som det har vist seg så mange ganger før langs kysten av Norge.

Geologiske undersøkelser har vist at området har deltatt i sterke bevegelser. Under den kaledonske orogenese skjedde det i en fase skyvninger rettet mot NV. Dette forårsaket en innfoldning av en rekke glimmerskifersoner i området mellom Grinde og Hermansverk (se kart fig. 1). Bergartene stryker stort sett NO—SV og faller mot SO. Et profil loddrett strøket er skjematisk fremstilt på fig. 2. Bergartene er i grensesonene sterkt breksierte, og slike breksiesoner fører ofte mye vann. Mellom Grinde og Hermansverk kan disse sonene ha en relativt stor mektighet, og 5—15 m tykkelse er ikke ualminnelig.

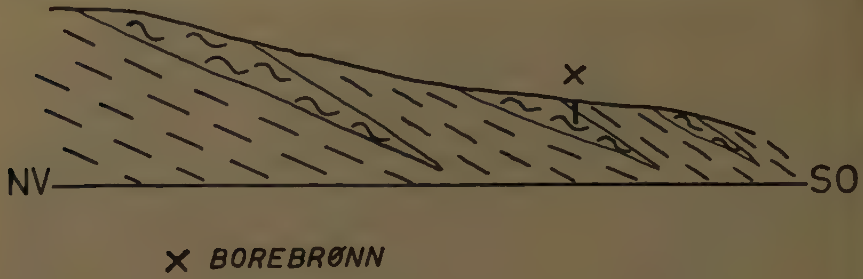

Fig. 2. Profilskisse av borebrønnenes beliggenhet i relasjon til grensen gneis—glimmerskifer.

Av kartet og profilet fremgår det at borhullene er meget gunstig plasert nær en slik breksiesone. Den innfoldete glimmerskifersone går fra Leikanger over Hamrestøl, Vålavatn, Husbyggestøl til Kleppane. Kartet viser også at terrenget stiger sterkt opp fra sjøen, og breksiesonen får følgelig et relativt steilt fall. Den vannledende sone når på strekningen Hamrestøl—Kleppane en høyde på 400—450 m o.h. Nettopp på denne strekningen må vi anta at nedtrengningsområdet for vannet er, for her løper breksiesonen ut i dagen i sitt høyeste nivå. Høydeforskjellen mellom nedtrengningsområdet og borhullene er ca. 450 m, og vannet vil derfor stå under trykk i disse. Sjøvannet hindres derved i å trenge inn i borhullet ved Leikanger Hotell, i hvert fall så lenge forbruket er lite i forhold til tilsiget. At trykket er større i borhullet på Husabø enn ved Leikanger Hotell kan skyldes at det er en «innstrupning» av den vannførende sone der. En slik «innstrupning» vil føre til en økning i vanntrykket.

Det er sikkert mye vann som følger denne breksiesonen. Mellom Hamrestøl og Kleppane er der en oppmagasinering av vann i myrer, særlig i området ved Vålavatn. Vi må kunne anta at disse områdene vil kunne gi opphav til stadig tilsig av vann i breksiesonen. Forholdene må således sies å ligge gunstig til med en jevn tilførsel av vann året rundt.

Boringene i Leikanger viser hvordan et gunstig resultat avhenger av at en tar hensyn til de lokale geologiske forhold, og hvorledes vannføringen er nær knyttet til de strukturelle svakheter i undergrunnen.

Manuskript mottatt 15. januar 1957.

Trykt august 1957.

NY LITTERATUR.

EDUARD BURKART (d. 1941): *Mährens Minerale und ihre Literatur.* Utgitt av det tsjekkoslovakiske vitenskapsakademi i Prag ved dr. THOMAS KRUT'A, 1953. 1005 sider, 1 portrett. Tysk tekst. Titel og forord også på tsjekkisk.

Et eksemplar av denne store monografi, som var dr. Burkarts livsverk, er sendt Mineralogisk institutt av dr. Krut'a, som nå bestyrer den mineralogisk-petrografiske avdeling av Landesmuseum i Brünn. Verket innledes ved forord av Krut'a og Burkart, minneord over Burkart av Zd. Jaroš, samt en liste over Burkarts arbeider. For øvrig faller det i 4 deler:

I. Litteraturliste (over 1500 nr.).
II. Fortegnelse over lokaliteter med tilhørende mineralbeskrivelser (ca. 800 s.).
III. Fortegnelse over mineralene med oppregning av deres finnesteder (ca. 90 s.).
IV. Register over finnesteder (over 1500) og over mineralspesies (over 400).

Boken er overordentlig detaljert, og stoffet er ordnet slik at man straks kan finne hvilke mineraler er kjent fra hver av de tallrike lokaliteter, og hvilke lokaliteter som fører et bestemt mineral. Lokalitetsnavn er gitt både i tsjekkisk og tysk form, til dels også i eldre, nå ikke brukelige former, noe som især for utlendinger er til stor hjelp. Boken er i det hele et mønster på et regional-mineralogisk oppslagsverk. Selvsagt har den størst interesse for de tsjekkiske mineraloger. Men mange mineraloger verden over vil finne den meget nyttig, ikke minst de som har med museenes mineralsamlinger å gjøre. Boken gir et levende inntrykk av områdets mineralrikdom, og av den virksomhet mineralogene i lang tid har utfoldet der. I litteraturlisten finner man en rekke av mineralogiens mest kjente navn fra eldre tid.

Ivar Oftedal.

NOTES ON SOME PALEOZOIC LOWER VERTEBRATES FROM SPITSBERGEN AND NORTH AMERICA.

By

Tor Ørvig

(Dept. of Paleozoology, Swedish Museum of Natural History,
Stockholm 50, Sweden).

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1. Abstract: This paper includes descriptions of Thelodontid scales (gen. et sp.indet.) and Acanthodian jaw-bones (*Atopacanthus* sp.) from the Devonian of Spitsbergen, and of a Petalichthyid Arthrodire, *Ellopetalichthys scheii* (KIÆR), from the Devonian of Ellesmere Land. Remarks are also given on the endoskeletal hard tissues in some representatives of the *Osteostraci* (*Benneviaspis*), the Brachythoracid Arthrodire (*Dunkleosteus*, etc.) and the Paleozoic Elasmobranchs (*Tamiobatis, Coelosteus*). The microstructure of the *Palaeomylus* tooth plates is dealt with, and the Ptyctodontid affinities of certain Ichthyodorulites from the Devonian of North America (*Eczematolepis, Gamphacanthus*) are discussed.

2. Introduction.

During my visit to the U.S.A. in 1953, for which I held a scholarship from the Norwegian Research Council for Sciences and the Humanities (Norges Almenvitenskapelige Forskningsråd), Oslo,[1] I had the opportunity, *inter alia*, of supplementing, and in some respects also of correcting, my earlier studies on the endoskeletal hard tissues of Placoderms and fossil Elasmobranchs (Ørvig 1951) by additional observation on various North American forms. The present paper contains remarks on those hard tissues in some Brachythoracid Arthrodires, particularly *Dunkleosteus*, from the Upper Devonian Ohio Shales formation, and in a few Selachians as well, e.g. *Coelosteus ferox* NEWB. from the Lower Carboniferous of Illinois. In addition, I have included here some few observations, made on the same occasion, on various Ptyctodontid tooth plates and Ichthyodorulites from the Devonian of Eastern U.S.A. For their kindness in placing all this material at my disposal, I wish to thank the authorities of the following museums: The American Museum of Natural History, New York City (Drs. G.G. Simpson, E. H. Colbert and B. Schaeffer); The Buffalo Museum of Science, Buffalo, N.Y. (Mr. F. T. Hall); The Cleveland Museum of Natural History, Cleveland, Ohio (Mr. W. E. Scheele); The Museum of Comparative Zoölogy, Harvard University, Cambridge, Mass. (Dr. A. S. Romer); The New York State Museum, Albany, N.Y. (Dr. W. Goldring); and The United States National Museum, Washington, D.C. (Dr. D. H. Dunkle). In the text, the names of those museums are abbreviated as AMNH, BMS, CMNH, MCZ, NYSM and USNM, respectively.

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[1] For acknowledgements, see Ørvig 1958.

In this paper, brief descriptions are also given of (a) *Macropetalichthys scheii* KIÆR from Ellesmere Land, which had been placed in a new genus, *Ellopetalichthys* n. g.; (b) certain Acanthodian jaw — bones from the Upper Middle Devonian of Mimerdalen, Spitsbergen, belonging to the genus *Atopacanthus* HUSSAKOF & BRYANT which is only known so far from the Devonian strata of Eastern U. S. A.; (c) detached Thelodontid scales, recently discovered in the Devonian of the Sørkapp Land, Spitsbergen; and (d) globular calcified cartilage in a member of the *Osteostraci*, *Benneviaspis holtedahli* STENSIÖ from the Red Bay Series of Spitsbergen. For the loan of all this material, I wish to express my indebtedness to Dr. A. Heintz of the Paleontological Museum, Oslo and, as far as *Atopacanthus* is concerned, also to Dr. P. Thorslund of the Palaeontological Institute of the Uppsala University. My thanks are also due to Dr. T. S. Winsnes of Norsk Polarinstitutt, Oslo for information concerning the Devonian stratigraphy of Sørkapp Land in Spitsbergen, and to Mr. J. M. Edmunds of the Dept. of Geology of the University Museum, Oxford, for the loan of an Arthrodire plate from the Lower Old Red Sandstone of Herefordshire (Grindrod Collection No. D8) which has been figured in this paper (fig. 12G). The latter specimen has earlier been described by Lankester (1870, p. 60, pl. 13, fig. 18) as a scute of a representative of the *Osteostraci*.

For technical assistance I wish to thank Mr. Elwood Logan of the American Museum of Natural History who, in New York, took some of the photomicrographs figured in this paper, and to the following members of the staff of the Swedish Museum of Natural History in Stockholm: Miss A. Brasch (preparation), Mr. U. Samuelson (photography) and Mrs. M. Liepina and Mr. S. Ekblom (drawings, retouching of photographs). The microphotographs reproduced on pls. 3 and 4 were taken with the aid of the excellent flat-field optics and high-extinction polarizing filters recently introduced by the Leitz Ltd. of Germany for the «Ortholux» microscope. This optical equipment has proved highly advantageous also for the study of thin sections of fossil hard tissue.

3. Ostracoderms from Spitsbergen.

a. Thelodontid scales from the Devonian of Sørkapp Land.

In the literature there seems to be no mention of Thelodontid scales from the Devonian strata of Spitsbergen (Vestspitsbergen), but as evidenced e.g.' by thin sections of bone bed material in the possession of the Paleontological Museum, Oslo and the Swedish Museum of Natural History, Stockholm, such scales are, in fact, not infrequently met with in various horizons of the Red Bay Series of the Northwestern part of the Island. As far as one can judge from this material, the scales are, on the whole, similar to those of broadly contemporary deposits elsewhere, e.g. the Upper Downtonian and Dittonian sequence of the Anglo-Welsh Borderland and Western Podolia. In addition, the thin sections at my disposal have also revealed that in Northwestern Spitsbergen some Thelodontid scales occur together with *Pteraspida*, *Dolichothoraci* and *Porolepidae* in various parts of the Kapp Kjeldsen Division of the Wood Bay Series, thus presumably at a somewhat higher stratigraphical level (Siegenian or younger, cf. Wängsjö 1952, p. 584; and others) than anywhere in Britain or on the European mainland.

Thelodontid scales also occur abundantly in some samples of fossiliferous Devonian rocks from the Southernmost part of Spitsbergen, the Sørkapp Land, collected during the geological mapping of this area recently carried out under the auspices of Norsk Polarinstitutt, Oslo (see Major & Winsnes 1955), and kindly submitted to me in Stockholm for identification. The latter scales, of which a short description is given in the sequel, are of some interest not only in that they are to some extent different from those described previously from various European and North American localities (see, e.g. Pander 1856, Rohon 1893; Traquair 1899a; 1899 b; 1905; Stetson 1928; Hoppe 1931; Kiær 1932; Brotzen 1934; Lehman 1937; Gross 1947; Bystrow 1949; 1955; etc.), but also in that they are derived from beds which in all probability are considerably younger than the Red Bay Series of Northwestern Spitsbergen and presumably even a little younger than the entire Wood Bay Series of that area. For a variety of reasons, above all the complicated situation with regard to the taxonomy of the *Thelodontida* which are known by isolated dermal elements only, I have found it most practical, for the time being at least, to refrain from giving the scales new generic of specific names.

THELODONTIDA GEN. ET SP.INDET.

Material. — At my disposal I had numerous scales of varying size and shape (figs. 2, 3), all contained in a few samples of a dark greyish, calciferous shale. In addition, this shale also exhibits a few small fin spines, presumably Acanthodian, but as far as I can find, it is devoid of any other vertebrate microfossils that can be determined

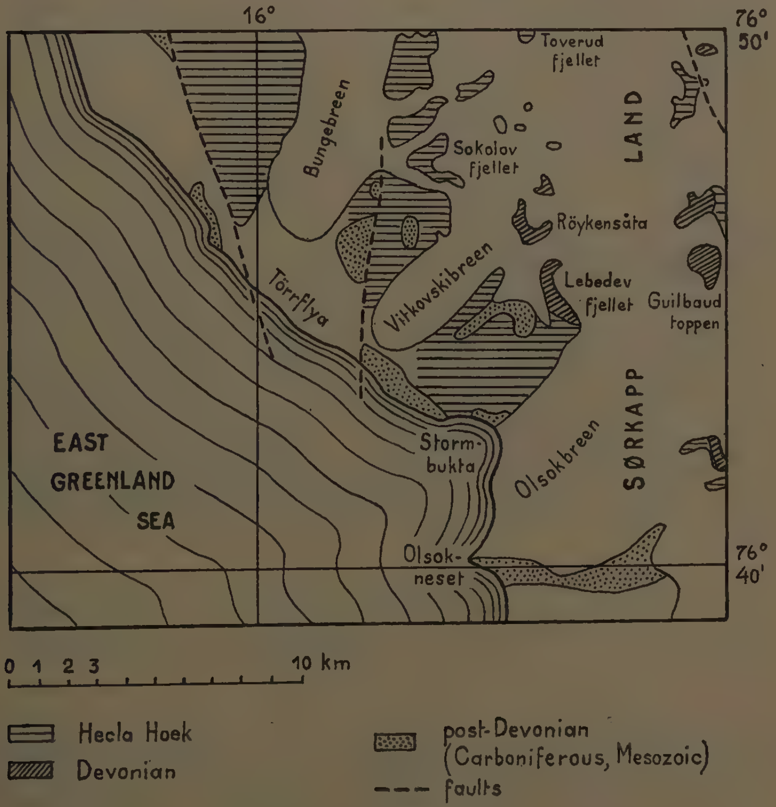

Fig. 1. Geological map of the Stormbukta area in Sørkapp Land, Southern Spitsbergen (Vestspitsbergen), somewhat simplified from Major & Winsnes 1955, fig. 1.

with any degree of certainty, and of Conodonts as well. On the other hand, it contains many Ostracod shells, mostly rather badly preserved, and possibly also other invertebrate fossils.

The scales dealt with here are black, with a faint bluish, or brownish, tint in those places where they have been subjected to weathering. The original substance of the hard tissues has, unfortunately, been replaced by heavy carbon compounds to such an extent that very little can be made out of the microstructure in sections. Most of the specimens figured here (fig. 3 A—C, D: 2, E—L) were freed from the matrix by dilute acetic acid. All the material belongs to the Paleontological Museum, Oslo (Nos. A 27128—27144).

Geological horizon and locality. — The samples containing the Thelodontid scales were collected in 1952 by Dr. T. S. Winsnes on the N side of the nunatak Røykensåta which rises above the glaciers in the Western part of the Sørkapp Land, about 7 km N of Stormbukta (fig. 1). The Devonian exposures on this nunatak have been visited previously by a field party belonging to the Hoel Spitsbergen Expedition of 1919, on which occasion some Ostracod material (*Isochilina?*, sp. cf. Solle 1935, pp. 40, 56) was brought together from a black, thin-bedded shale, presumably situated underneath the beds with Thelodontid scales dealt with here.

The Devonian shales in Røykensåta cannot at present be dated, even approximately, by their fossil contents. According to information kindly supplied by Dr. Winsnes, however, the general stratigraphy of the Devonian strata in the Stormbukta area may throw some light on this problem. Thus, in the mountain Lebedevfjellet, a little S of Røykensåta (fig. 1), there follow, on top of the Hecla Hoek, (a) red sandstones and conglomerates, presumably corresponding, in part at least, to the Stjørdalen Division of the Wood Bay Series of Northwestern Spitsbergen; and (b) greyish deposits which in all probability are broadly equivalent to the passage beds between the Wood Bay and Grey Hoek Series, or to the lower part of the Grey Hoek Series itself.[1] Since both in Røykensåta and in Lebedevfjellet the Devonian

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[1] A few samples of the greyish deposits of Lebedevfjellet which I have had the opportunity of investigating (collected by Mr. O. Jøsang in 1952) contain large tuberculated Arthrodire bones, rather similar to those of the lower part of the Grey Hoek Series of Andrée Land (Jacobsendalen, etc.) to the north.

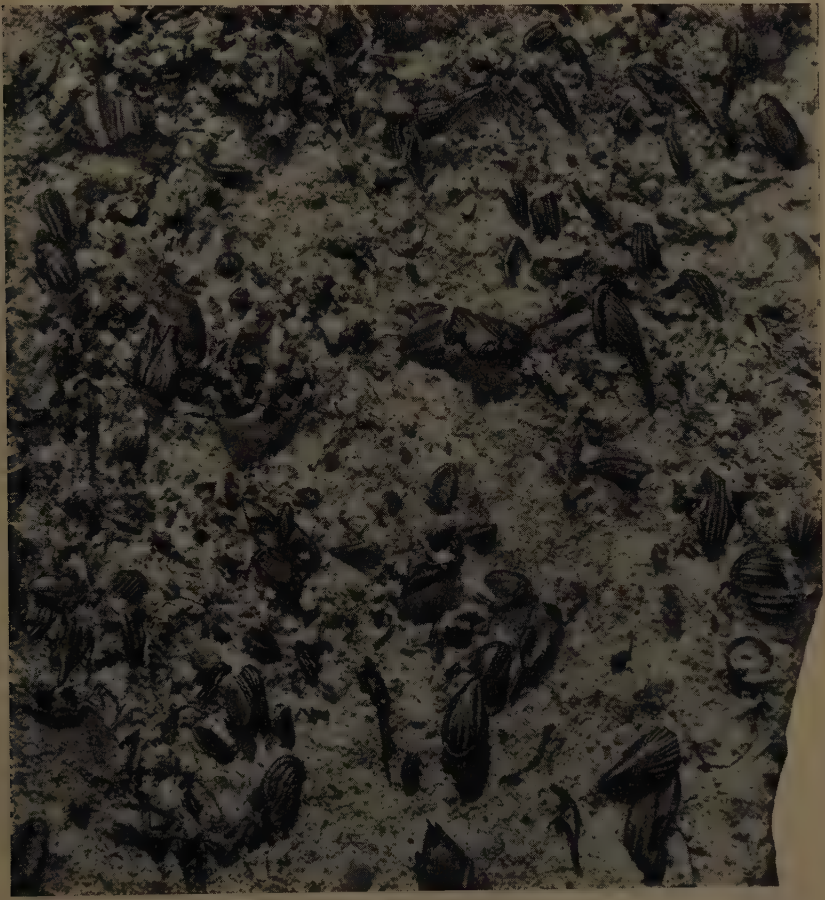
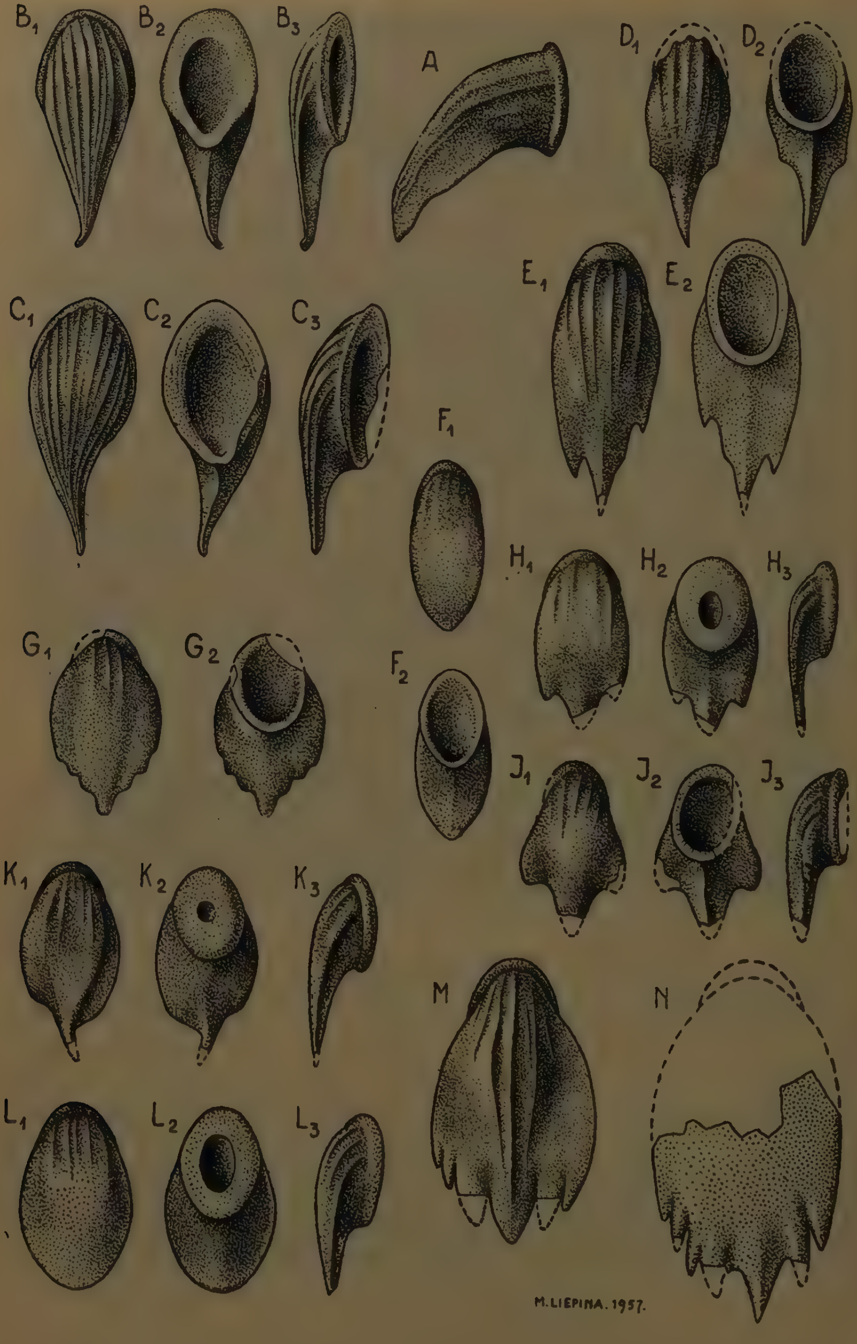


Fig. 2. *Thelodontida* gen. et sp. indet. Lower (or Middle?) Devonian, Røykensåta, Sørkapp Land. Scales weathered out on the surface of the rock. Specimen No. A 27128 belonging to the Paleontological Museum, Oslo, x 7.

strata dip to the north, everything goes to prove that the shales with Ostracods and Thelodontid scales from the former of those localities lie at a higher stratigraphical level than the grey beds just referred to from the latter. If this is true, it follows that the shales in Røykensåta may be correlated with some part of the Grey Hoek Series or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M. LIEPINA. 1957.

with still younger deposits and, consequently, that they are either Upper Lower Devonian or Middle Devonian in age.

It may be mentioned here, finally, that there are outcrops of dark Devonian shale, resembling those of Røykensåta, also in other nunataks of the same area, e.g. in Guilbaudtoppen to the east and Toverudfjellet to the north (fig. 1). In a sample of such shale from the latter locality, put at my disposal by Dr. Winsnes, there is a vertebrate fauna which is similar in many ways to that of certain parts of the Grey Hoek Series, containing i.a. tuberculated Arthrodire bones, *Porolepis* plates, fragments of Holoptychiid scales of the *Onychodus-Glyptolepis* variety (see Ørvig 1957 a, pp. 385—386, 395, figs. 4, 7 C—E) and various Crossopterygian teeth. As far as I can find, however, this fauna does not include any Thelodontid scales whatever.

Description. — The great majority of the scales range between 0.7 and 2.4 mm in length, but fragments of even larger specimens are also met with (fig. 3 N). As far as their order of size is concerned, therefore, they clearly surpass all other Thelodontid scales, whose maximum length rarely exceeds 1 mm in the Upper Silurian and Downtonian forms in general (see Gross 1947, p. 99), and may reach 1.7 mm, or thereabouts, in the Dittonian *Turinia* (*Cephalopterus*) *pagei* (Traquair 1899 a, pl. 1, figs. 5, 6). As in *Phlebolepis*, *Thelodus*, *Turinia*, etc., they are made up of a basal plate and a crown, separated from each other by a somewhat constricted neck-portion. The basal plate is rather small and low, and it is not produced anteriorly into a process as frequently is the case in other Thelodontid scales (see, e.g. Gross 1947, pl. 22, figs. 1—9, 13). The opening of the pulp cavity on the basal side of the scales varies somewhat in width, but is mostly

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Fig. 3. *Thelodontida* gen. et sp. indet. Lower (or Middle?) Devonian, Røykensåta, Sørkapp Land. Scales, orientated with their anterior margin upwards; x 15. One specimen (*A*) shown in lateral view and two (*M*, *N*) in superficial view only, the others in superficial (*1*) and basal views (*2*) and, in some cases (*B*, *C*, *H–L*), also in lateral view (*3*). The superficial and basal faces of the scale in *D* drawn from two different specimens. The scales figured in *A–C*, *D:2*, *E–L*, freed from the matrix by dilute acetic acid. All specimens belonging to the Paleontological Museum, Oslo. *A*, No. A 27131; *B*, No. 27132; *C*, No. A 27133; *D:1*, No. A 27130a; *D:2*, No. A 27134; *E*, No. A 27135; *F*, No. A 27136; *G*, No. A 27137; *H*, No. A 27138; *J*, No. A 27139; *K*, No. A 27140; *L*, No. A 27141; *M*, No. A 27128a; *N*, No. A 27130b.

very large. The neck-portion is entirely without any openings for vascular canals, a circumstance by which the scales, like those of the other *Thelodontida*, are clearly distinguishable from the typical «placoid organs» of the Elasmobranchs in general.

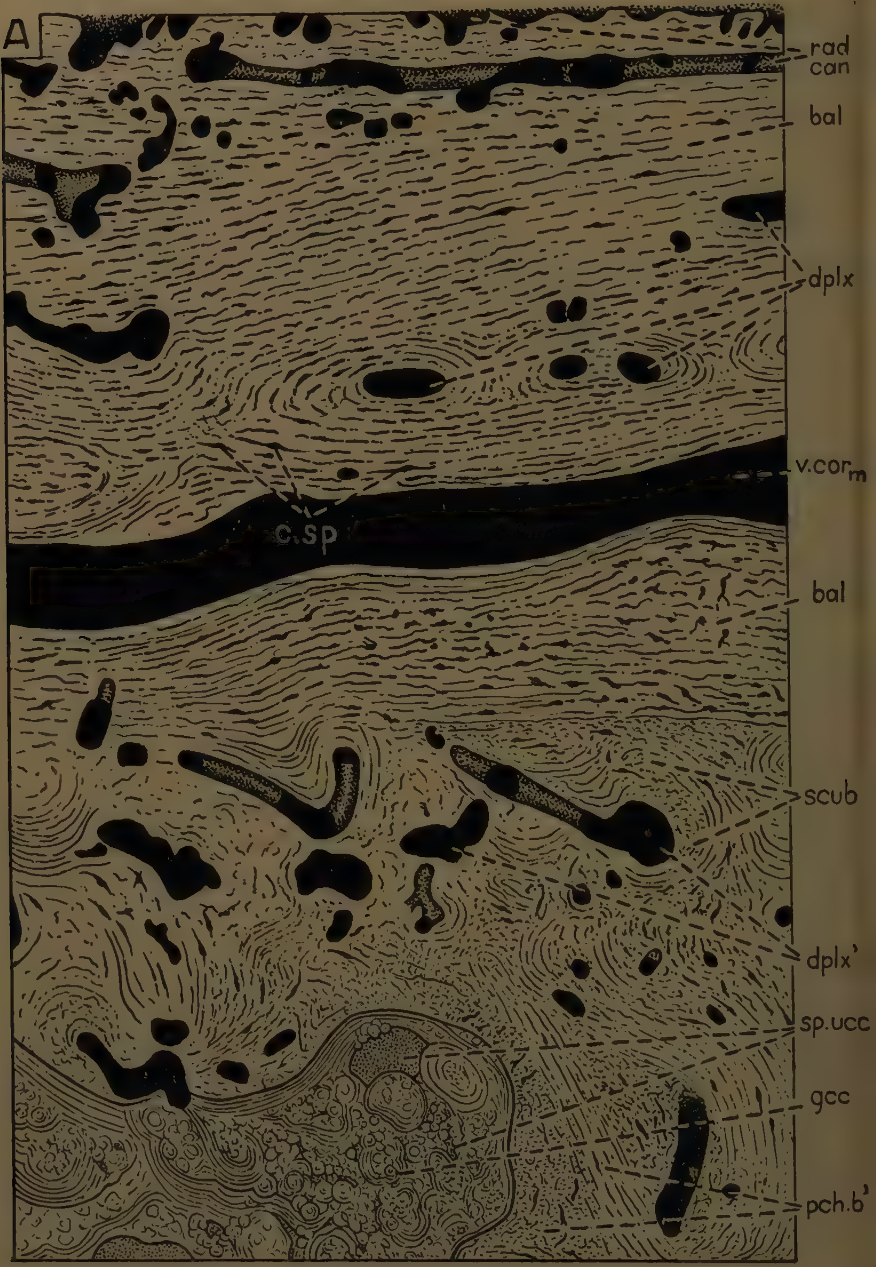
In one kind of scale, which in the material at my disposal is represented by a single specimen only, the crown is rather high, gently curved backwards, and somewhat suggestive of that in the scales of *«Lanarkia» costata* Gross and *«L»*. sp. from the erratic *Beyrichia* Limestone of Northern Germany and the Ludlow Bone Beds of the Anglo-Welsh Borderland where its shape and other properties are concerned (fig. 3A; see Gross 1947, pp. 109–110, pl. 21, figs. 9–13; cf. also Lehman 1937, pl. 2, fig. 28). In the other scales, however, the crown is always low and elongated in a posterior direction (figs. 2, 3 B—N). In several specimens it is reminiscent of that in the scales of *Lanarkia horrida* Traq. and *L.spinosa* Traq. from the Upper Silurian Lesmahagow beds of Scotland (Traquair 1899 b, pl. 3, figs. 3, 4, 6, 9—12; Ørvig 1958) and, to some extent, also of that in the Thelodontid scales described by Spjeldnæs (1950, pl. 1, figs. 1 a, 3 a) from the Upper Silurian of Gotland, in that it is more or less horn-like, tapering to a point posteriorly and ornamented with a number of longitudinal ridges which converge backwards (figs. 2, 3 B, C). In many other specimens, which in some respects bear a superficial resemblage to the «placoid organs» of various Mesozoic and Cenozoic Selachians, more so, in fact, than the Thelodontid scales of the customary kind, the crown is either tricuspidate (fig. 3 H, J) or, as i.a. in all the particularly large specimens, rather flat and broad, roughly elliptical or somewhat leaf-like in superficial view, frequently with a series of cusps along its posterior margin, and generally smooth except for a few longitudinal ridges in the anterior, or central, part of its top face (fig. 3 L—N).

It will be evident from the above and from the accompanying illustrations as well (figs. 2, 3), that the scales show a wide range of variation, especially with regard to the shape of their crown. Despite this, however, it is hardly possible to select any specimens, so clearly set apart from the others that one can place them in a separate, well-defined group, or refer them to a taxonomical unit of their own. It is thus obvious that there is a gradual transition, by a series of intermediate types, between the scales with horn-like, tricuspidate and leaf-like crowns just referred to (cf. fig. 3 D—G, K), and there can be little doubt, I think, that in a more comprehensive material than that now available, this will turn out to be true also of the scales with high and low crowns, respectively (cf. fig. 3 A, B:3, C:3). In such circumstances there is reason to believe that the whole assemblage of scales now under consideration belongs either to one, or perhaps more likely, to a few closely related forms, concerning whose affinities nothing more can be said at present than that they cannot possibly be congeneric with any of the previously described representatives of the *Thelodontida*. It is true, as noted above, that some of the scales show a certain resemblance to those of *Lanarkia* from the Upper Silurian Lesmahagow beds of Scotland, but on such slender evidence one can hardly conclude, in my opinion, that we are here concerned with any form or forms, even distantly related to that particular genus.

b. The endoskeletal hard tissues of *Benneviaspis holtedahli* STENSIÖ from the Red Bay Series.

In the *Osteostraci*, as is well known (Stensiö 1927; 1932; Wängsjö 1952; and others), the external surfaces and many of the interior cavities and canals of the endoskeleton of the cephalic shield are frequently lined with perichondral bone layers. In *Boreaspis* (Stensiö 1927, p. 296, pls. 14, 15; Ørvig 1951, foot-note 1 on p. 430; Wängsjö 1952, p. 52, *end*, pl. 117, figs. 2, 3), the endoskeleton also exhibits cancellated enchondral bone, a circumstance which, as evidenced by the ENS material investigated by Wängsjö, is also true of *Nectaspis* from the Wood Bay Series. Calcified cartilage has not been recorded so far in any of the *Osteostraci* from Spitsbergen or elsewhere, but, rather to my surprise, I recently found that this hard tissue occurs abundantly in the endoskeletal shoulder girdle of a specimen of *Benneviaspis holtedahli* Stensiö from the Ben Nevis Division (Dittonian) of the Red Bay Series which I had the opportunity to section. In this specimen the conditions are the following.

In the zonal part of the cephalic shield, more precisely on the medial side of the cornu, the exoskeleton exhibits a rather thick basal layer which, as normally in the *Osteostraci*, consists of laminated bone tissue with a great many cell-spaces (*bal, c.sp*, fig. 4 A). Underneath the basal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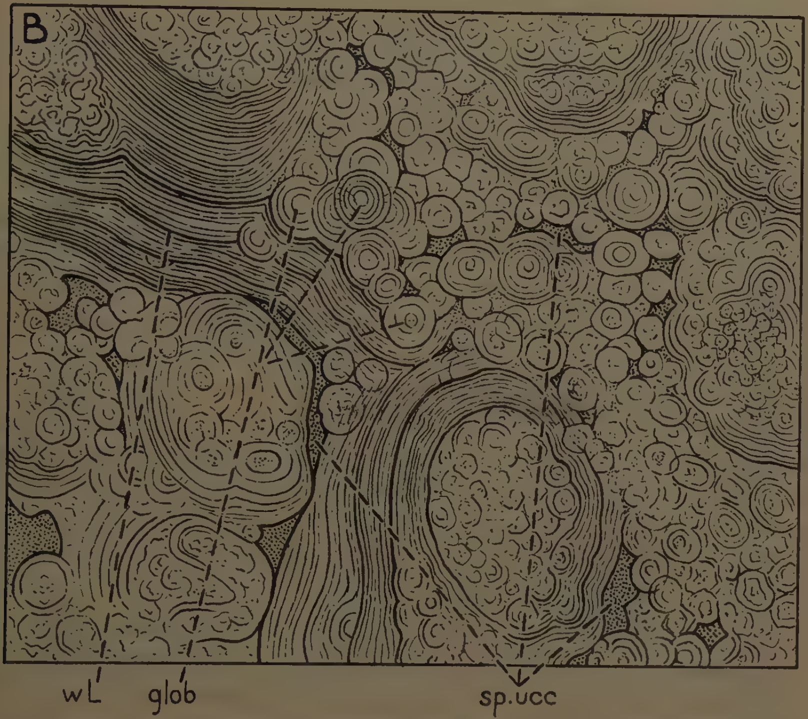

Fig. 4. *Benneviaspis holtedahli* Stensiö. Dittonian, Red Bay Series, Ben Nevis Division, *Benneviaspis* horizon, Mount Ben Nevis, Northern Spitsbergen (Vestspitsbergen). *A*, oblique horizontal section, showing the middle and basal layers of the exoskeleton on the medial side of the cornu (the superficial «dentine» layer of the exoskeleton is incompletely preserved), the subcutaneous bone tissue and the perichondral bone layer and calcified cartilage of the endoskeleton of the shoulder girdle, from Specimen No. A 30004b belonging to the Paleontological Museum, Oslo, counterpart of No. A 30004a, figured by Wängsjö (1952, pl. 71, fig. 2); x 150. *B*, more highly magnified detail of the calcified cartilage in *A*, x 500.

bal, basal layer of the exoskeleton; *c.sp*, cell-spaces; *dplx*, *dplx'*, canals belonging to the subcutaneous (subaponeurotic) vascular plexus in the basal layer of the exoskeleton, and in the subcutaneous bone tissue, respectively; *gcc*, globular calcified cartilage; *glob*, globules; *pch.b'*, perichondral bone layer, not well defined from the subcutaneous bone tissue; *rad.can*, radiating vascular canals in the middle layer of the exoskeleton; *scub*, subcutaneous bone tissue; *sp.ucc*, matrix-filled spaces, originally containing isles of uncalcified cartilage; $v.cor_m$, canal for the vena cornualis medialis (cf. Wängsjö 1952, *vcm*, pl. 71, fig. 2). *wL*, waves of Liesegang in the globular calcified cartilage.

layer of the exoskeleton there follow (a) a layer of subcutaneous bone tissue, varying in thickness, with numerous, irregularly distributed vascular canals (*scub*, fig. 4 A); (b) a layer of perichondral bone, continuous with, but mostly rather indistinctly bounded off from, the subcutaneous bone tissue (*pch.b*, fig. 4 A); (c) a well-developed, subperichondral layer of globular calcified cartilage, always sharply demarcated from the perichondral bone superficial to it; and (d) a cancellated mass of globular calcified cartilage which from the subperichondral calcified layer extends into the interior of the endoskeletal shoulder girdle (*gcc*, fig. 4). The globular calcified cartilage is made up of clusters of globules, surrounded by «waves of Liesegang» (*glob*, *wL*, fig. 4 B), and both in ordinary and polarized light it shows the same structure as the corresponding hard tissue of Arthrodires, Acanthodians, Elasmobranchs and various Actinopterygian fishes, earlier dealt with by the present writer (gcc_{sp}, fig. 8 B; see Ørvig 1951, pp. 400—401, 410, 414—415, 419—421, 423, 431, *gcc*, gcc_1, figs. 15, 17, 18, 20 A, C, E, 21, pls. 4, 5, pl. 6, figs. 2, 4, 5, pl. 7, figs. 1, 3, pl. 8; see also Schmidt 1955, fig. 1). Such calcified cartilage very probably occurs also in other parts of the endoskeleton of the cephalic shield, but on the basis of the material of my disposal I have been unable to decide to what extent this is true.

The fact just referred to, that globular calcified cartilage in all respects similar to that of Placoderms, Elasmobranchs and other fishes, is met with in a representative of the *Osteostraci*, may be of some interest from the point of view of comparative histology. In *Benneviaspis* this hard tissue cannot very well have formed in a muco-cartilage corresponding to that of the *Petromyzon* larva; — much more likely is that it arose ontogenetically in the same way as in the Elasmobranchs, i.e. by the precipitation of lime-salts in the ground substance of a cartilage which may have been intermediate, to some extent at least, between precartilage and typical hyaline cartilage («gemischter Vorknorpel», see Ørvig 1951, pp. 350, 429; and the literature cited in that work). In *Benneviaspis*, therefore, the endoskeleton very probably was made up completely, or at any rate predominantly, of true cartilage, and I can find no reason why this should not be true of the other *Osteostraci* as well. As pointed out by Johnels (1948, pp. 243—247, 268—270), the muco-cartilage of the immature *Petromyzon* may be special kind of cartilaginous connective tissue which came into being rather late in the history of the *Cephalaspidomorphi* as a replacement of the cartilage proper originally existing in the endoskeleton of the early members of the group, including the *Osteostraci*.

Another circumstance worth noticing here is that *Benneviaspis*, where the endoskeleton contains globular calcified cartilage, and *Boreaspis*, where it exhibits enchondral bone, both belong to the same order of the *Osteostraci* (the *Orthobranchiata*, Stensiö 1957, pp. 212—214). It is possible, therefore, that in this order, globular calcified cartilage and enchondral bone are substitutional hard tissues, just as they are in *Bobasatrania* among the Ganoids (Ørvig 1951, p 431).

Globular calcified cartilage has not yet been found in any of the *Heterostraci*, but in view of the condition of *Bonneviaspis* dealt with above, it may well occur even in this group of the Paleozoic *Agnathi*. It may be mentioned here, for instance, that detached pieces of globular calcified cartilage are associated with dermal elements of *Astraspis* and *Eriptychius* in the Harding Sandstone of Colorado and various other Ordovician deposits of the Cordilleran Region of the U. S. A. (Ørvig 1951, pp. 383, 415, fig. 18 A; 1957 b). This may be entirely coincidental, as I have earlier believed (1951, p. 381), but it may also mean that in one, or both, of those forms the endoskeletal cartilage was calcified to some extent.

4. Arthrodires from North America.

a. *Ellopetalichthys scheii* (KIÆR) from Ellesmere Land.

From the marine Series D of the Devonian strata in Southwestern Ellesmere Land Kiær, in 1915, described a species of *Macropetalichtys*, *M.scheii* which, in the material at his disposal, was represented by a single specimen only. Kiær (1915, pp. 13—15, fig. 2) distinguished this form from the other *Petalichthyida* known at that time on the basis on such characters as the shape and proportions of the dermal skull-roof, the size of the orbital openings and certain details in the development of the lateral line canal system, and found that in those respects, it is, on the whole, closer to *M.hoeninghausi* (v. Meyer) than to *M.rapheidolabis* Norwood & Owen. Since Kiær's description was published, *M.scheii* has been referred to very briefly, or not commented upon at all, in the literature dealing with the Petalichthyid Arthrodires (Stensiö 1925, and subsequent papers; Jaekel 1926; Stetson 1930; Gross 1933 b; 1937; 1950; Heintz 1937; Woodward 1941; White 1952; and others). As is now evident, however, this form is, in fact, of more interest than hitherto assumed in that the holotype, in addition to the incompletely preserved dermal skull-roof dealt with by Kiær, also exhibits ossifications in the posterior part of the endocranium. As shown by those ossifications, the species differs to such an extent from the type species of *Macropetalichthys*, *M.rapheidolabis*, that it can hardly belong to the same genus as the latter. For this reason it is here placed in a new genus which may be briefly defined as follows.

Class Elasmobranchiomorpha

(including *Arthrodira*, *Acanthodii*, *Selachii* and *Bradyodonti*).

Subclass Arthrodira.

Superorder Euarthrodira.

Order Petalichthyida.

Genus *Ellopetalichthys* n.g.

Diagnosis. — A genus of *Petalichthyida* of fairly small size. Dermal bones of skull-roof ornamented with low tubercles. (Arrangement of dermal bones not known in detail). Orbital openings very large, oval. Lateral line canals fairly wide, opening to the exterior with single rows of pores. Supraorbital canals meeting posterior pit-line canals at about half the entire rostro-caudal length of skull-roof. (Ethmoidal, orbitotemporal and otic regions of endocranium presumably without ossifications). Occipital region of endocranium with two perichondral ossifications, anterior and posterior.

Type species. — *Macropetalichthys scheii* Kiær, 1915.

Derivatio nominis. — The generic name is derived from the first letters of Ellesmere Land, *πέτᾰλον* — leaf, and *ιχϑὺς* -fish.

Remarks. — The above diagnosis, which is based on the holotype (and only existing specimen) of the type species, is incomplete in certain respects. Very little can be said, for instance, concerning the shape and relations of the dermal bones, particularly in the critical area on the preorbital part of the head. On the basis of the diagnostic characters, as they are now known, it is nevertheless possible, in my opinion, to distinguish *Ellopetalichthys* n.g. from the other genera of the *Petalichthyida*, viz. *Macropetalichthys* NORWOOD & OWEN, *Epipetalichthys* STENSIÖ, *Lunaspis* BROILI and *Notopetalichthys* WOODW. The evidence may be briefly summarized as follows.

(1) In the shape of the dermal skull-roof and in the distribution of the lateral line system, *Ellopetalichthys* n.g. is, on the whole, more suggestive of *Macropetalichthys* than of the other *Petalichthyida* (fig. 5). However, it is distinguishable from the latter genus by (a) the large size of the orbital openings (*orb*, fig. 5 A, F), (b) the circumstance that the endocranium, as far as one can judge, only possessed two separate perichondral ossifications, both situated in the occipital region, (*Oc. a. Oc. p*, fig. 7 A), and (c) the general shape of the posterior part of the endocranium as revealed by those ossifications (fig. 7). By the same characters it is also separable from *Epipetalichthys* (figs. 5 B, F, 7 A; Stensiö 1925, fig. 18). From the latter genus it also differs in that the supraorbital canals extend so far backwards as to connect with the posterior pit-line canals at the radiation center of the centro-nuchal plate (*soc*, *pp*, fig. 5 B, F).

(2) *Ellopetalichthys* n.g. differs from *Lunaspis* (as represented by the type species, *L.heroldi* BROILI and the other German species) in the ornamentation of the dermal bones, the proportions of the skull-roof and the course and relations of some of the lateral line canals (fig. 5 C, F). Since those characters are identical, or very nearly so, with several of those dealt with by Gross (1937, pp. 48—49) for the distinction between *Macropetalichthys* and the German *Lunaspis* material, they need no further comment here.[1] By much the same characters as

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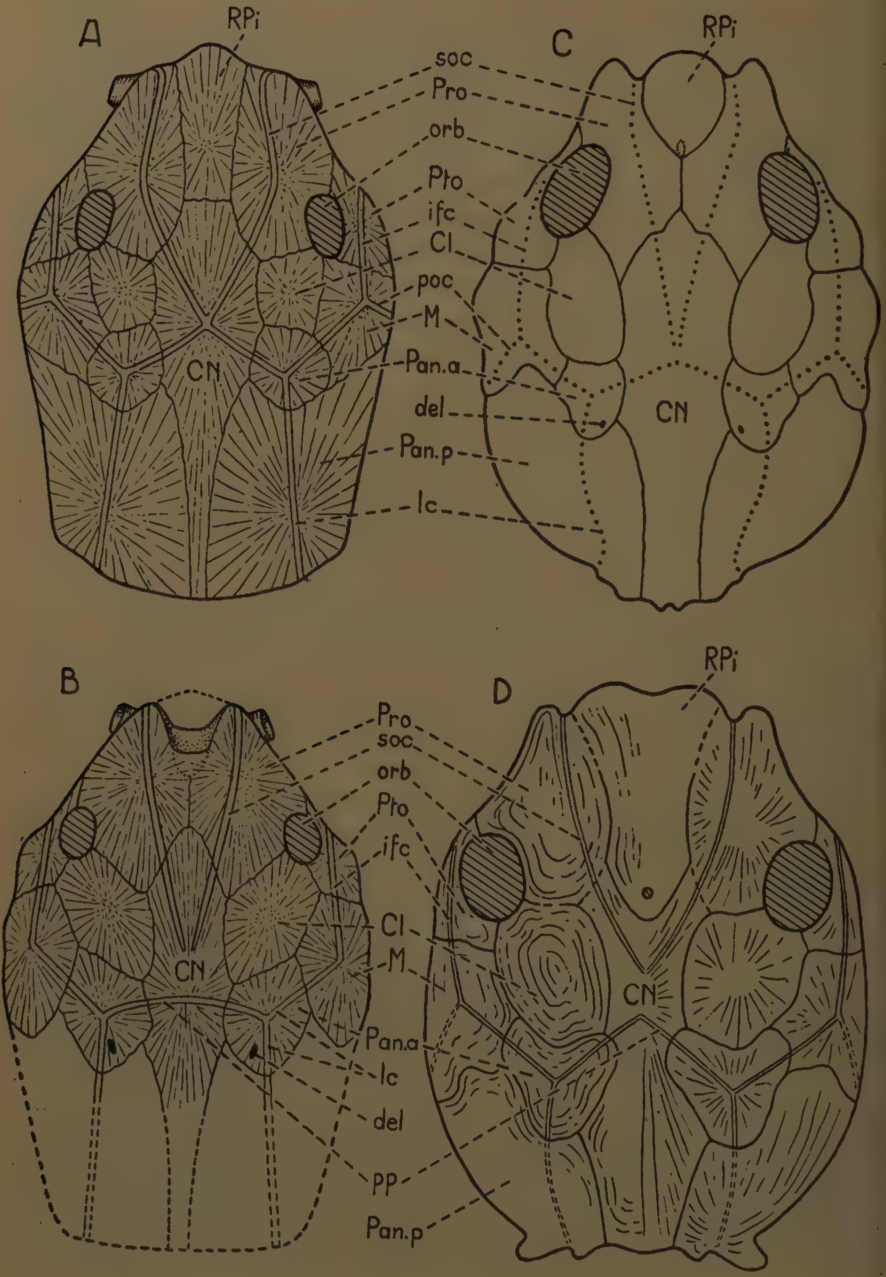
[1] In *Ellopetalichthys* n. g. the most anterior part of the head is unknown, but it is a fair inference that, as in *Macropetalichthys*, the junction between the supraorbital and posterior pit-line canals lies practically halfways between the anterior tip of the rostral (or rostro-pineal) plate and the posterior end of the centro-nuchal plate, or more precisely, that the posterior part of the head is rather long (fig. 5A, F; see Kiær 1915, fig. 2d). In *Lunaspis* from Germany and Spitsbergen, on the other hand, at least in the material where the state of preservation is sufficiently good to allow exact measurements, this part of the head is shorter, proportionally, in that the distance from the radiation center of the centro-nuchal plate to the posterior margin of this plate is less than half the entire rostro-caudal length of the head (fig. 5C, D). In *Lunaspis*, furthermore, the supraorbital canals are not connected posteriorly with the posterior pit-line canals (*soc*, *pp*, fig. 5C. D).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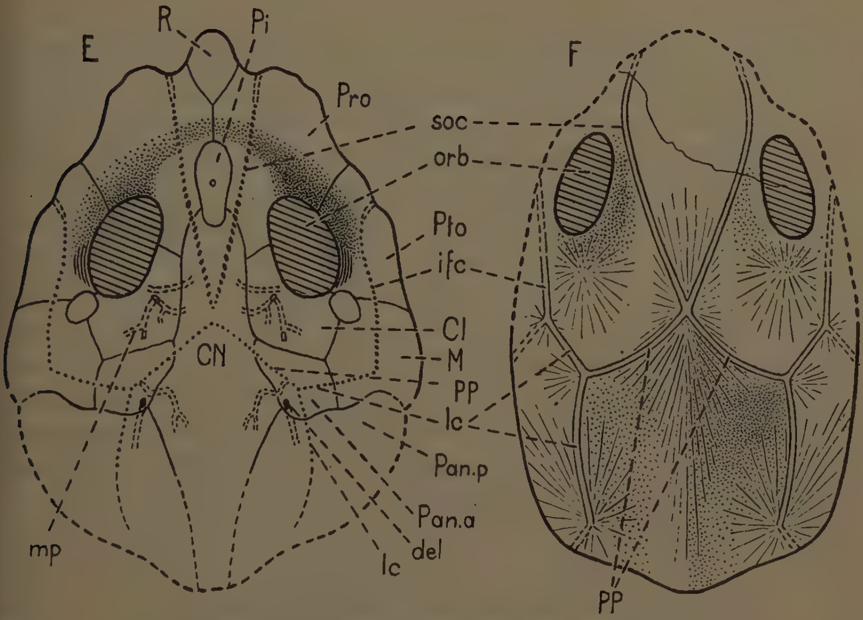


Fig. 5. Restorations of the dermal skull-roof in six representatives of the *Petalichthyida*, drawn to such a scale that the distance from the tip of the snout to the posterior end of the centro-nuchal plate is the same in all figures. *A*, *Macropetalichthys rapheidolabis* Norwood & Owen, Lower Middle Devonian, Onondaga Limestone, New York, from Stensiö 1925, fig. 15; *B*, *Epipetalichthys wildungensis* Stensiö, Lower Upper Devonian, *Manticoceras* beds, Wildungen, Germany, from Stensiö 1925, fig. 19; *C*, *Lunaspis* [based on *L. prümensis* (Kayser) and *L. broilii* Gross], Upper Lower Devonian, Rhineland, Germany, from Gross 1937, fig. 28A; *D*, *Lunaspis arcticus* (Heintz), Upper Lower (or Middle) Devonian, Grey Hoek Series, Spitsbergen, from Heintz 1937, fig. 2; *E*, *Notopetalichthys hillsi* Woodw., Middle Devonian, New South Wales, somewhat altered from White 1952, fig. 37; *F*, *Ellopetalichthys scheii* (Kiær), Upper (?) Middle Devonian, Ellesmere Land, partly based on Kiær 1915, fig. 2d.

Cl, lateral central plate; *CN*, centro-nuchal plate; *M*, marginal plate; *Pan.a*, *Pan.p*, anterior and posterior paranuchal plates; *Pi*, pineal plate; *Pro*, preorbital plate; *Pto*, postorbital plate; *R*, rostral plate; *RPi*, rostro-pineal plate. *del*, external opening for the ductus endolymphaticus; *ifc*, infraorbital lateral line canal; *lc*, cephalic division of the main lateral line canal; *mp*, middle pit-line canals; *orb*, orbital opening; *poc*, preopercular lateral line canal; *pp*, posterior pit-line canal; *soc*, supraorbital lateral line canal.

those just referred to, (fig. 5 D, F) *Ellopetalichthys* n.g. is also easily separable from the Spitsbergen form, *L. arcticus* (HEINTZ), which, very probably, does not belong to *Lunaspis*, but to a genus of its own.

(3) *Ellopetalichthys* n. g. is suggestive of *Notopetalichthys* in that it has unusually large orbital openings which, however, are not nearly as oblique as in the latter (*orb*, fig. 5 E, F). A detailed comparison cannot be made at present between those two genera since, in both of them, the shape of the dermal skull-roof is incompletely known. Everything seems to show, nevertheless, that they are distinguishable from each other by such characters as the proportions of the skull roof, the ornamentation of the dermal bones and the course and relations of several of the lateral line canals on the postorbital part of the head (fig. 5 E, F). In *Ellopetalichthys*, furthermore, there seems to be no brim-like, depressed area on the preorbital part of the dermal skull-roof, similar to that in *Notopetalichthys* (Woodward 1941, pl. 1, fig. B; White 1952, pp. 283, 285, fig. 37).

Ellopetalichthys scheii (KIÆR).

1915. *Macropetalichthys scheii* new species —, J. Kiær, pp. 9—12, figs, 1, 2 d, pl. 1.
1929. *Macropetalichthys schei* KIAER —, O. P. Hay, p. 645.
1932. *Macropetalichthys scheii* KIAER —, G. Säve-Söderbergh, p. 33.
1937. *Macropetalichthys scheii* —, A. Heintz, p. 6.
1941. *Macropetalichthys scheii* KIAER —, A. S. Woodward, p. 95.
1950. *Macropetalichthys scheii* KIAER —, W. Gross, p. 46.
1951. *Macropetalichthys scheii* KIÆR —, T. Ørvig, p. 409.

Diagnosis. — Same as for genus (single species).

Holotype. Specimen No. A 13047 (figs. 5 F, 7 A, pl. 1), and counterparts Nos. A 13048–49, belonging to the Paleontological Museum, Oslo.

Geological horizon and locality. — Upper (?) Middle Devonian, upper part (h) of Series D; Goose Fiord, Southwestern Ellesmere Land. Kiær (1915) did not state from which part of the Goose Fiord area the holotype came, but according to the original label of the collector (Mr. P. Schei) accompanying the specimen, it is from a locality on the W side of the fiord. As concerns the dating of the Series D, which is based largely on the evidence of its Brachiopod fauna, there has been some discrepancy (see Kiær 1915, pp. 15—16, 53; Säve-Söderbergh 1932, p. 33; and others). Since, however, the overlying Series E has yielded various vertebrate fossils presumably belonging to the lowermost Upper Devonian (see Ørvig 1957 a, pp. 377—378, 415; and the references cited in that paper), and for other reasons too, one may assume that Series D most probably is of an Upper Middle Devonian age.

DESCRIPTION.

Exoskeleton. —— The features of the dorsal side of the head, as they are disclosed in the holotype (pl. 1, fig. 1), were rather thoroughly dealt with by Kiær (1915, pp. 9—12), and not very much can, in fact, be added to his descriptions. In dorsal view the head is elongated and roughly ellipsoidal in outline (fig. 5 F). The orbital openings are very large and situated far apart (*orb*, fig. 5 F, pl. 1, fig. 1), and in them one can detect no traces of episclerotic plates (cf. Ørvig 1958) or of sclerotic ossifications proper.

The hind part of the dermal skull-roof shows clearly that, as in many other Arthrodires, the exoskeleton of the head articulated against that of the shoulder girdle by means of a strong cervical joint. On each side of the head, close to its posterior border, a thick process protrudes in a ventral direction from the posterior paranuchal plate, and on the lateral side of this process there is a distinct glenoid fossa which no doubt received a forwardly directed trochlea belonging to the anterior dorsolateral plate of the shoulder girdle (*pr.v. f.gl*, pl. 1, figs. 2–4) The glenoid fossa is not transverse as in most *Brachythoraci*, but parallel to the axis of length of the head. An exoskeletal cervical joint is probably developed also in *Lunaspis* (Heintz 1937, pp. 6–7, *k*, figs, 1, 2, pl. 1, fig. 1), but it cannot be said at present whether, with regard to its construction, this joint was of about the same kind as in *E. scheii*, or more like that in the *Brachythoraci* in general.

The dermal bones are highly reminiscent of those in the North American and German *Macropetalichthys* species with regard to their ornamentation (*t*, pl. 1, fig. 5; cf. Newberry 1889, pl. 38, fig. 2; Eastman 1907, pl. 9, fig. 5; Gross 1933b, pl. 8, fig. 4) and their microstructure as well (Kiær 1915, pl. 1, fig 6; cf. Gross 1933b, pp. 52–53;

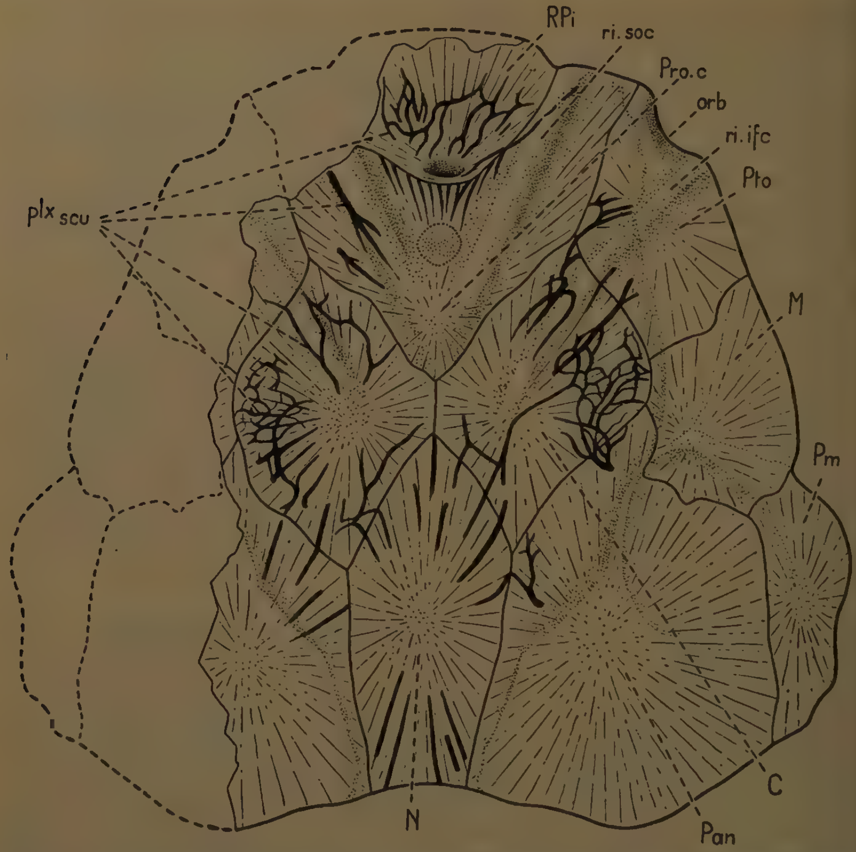


Fig. 6. *Actinolepis?* sp. Lower Devonian, Wood Bay Series, Lykta Division, 2nd Mountain N of Garborgfjellet, E side of Ekmanfjorden, Spitsbergen (Vestspitsbergen). Dermal skull-roof in ventral view; ENS-Specimen, Field-No. 449; natural size.

C, central plate; *M*, marginal plate; *N*, nuchal plate; *Pan*, paranuchal plate; *Pm*, postmarginal plate; *Pro.c*, preorbital plates of both sides fused into a single bone; *Pto*, postorbital plate; *RPi*, rostro-pineal plate. *orb*, orbital opening; plx_{scu}, canals of a subcutaneous vascular plexus situated close underneath the basal layer of the dermal bones (denoted with black); *ri.ifc*, *ri.soc*, ridges on the ventral face of the dermal skull-roof corresponding to the infraorbital and supraorbital lateral line grooves, respectively.

1935, pp. 29–30, fig. 9, pl. 6, fig. 4). The tubercles in the superficial layer of the bones consist of the same kind of semidentine (see Ørvig 1958) as in *M. hoeninghausi* and *M. rapheidolabis* (Gross 1935, loc.

cit.; the writers observations on various material; see also Wells 1944, pl. 8, fig. 2), but in contradistinction to what is generally the case in these forms, they seem nowhere to be superimposed by other tubercles belonging to subsequent generations. As normally in the *Petalichthyida*, the middle layer of the dermal bones contains comparatively coarse vascular canals which are separated from each other by thin bony trabeculae, and are arranged in such a way as to radiate from the center of the individual bones out towards their margins. The basal layer of the dermal bones, finally, is much thinner, proportionally, than the corresponding layer of *Macropetalichthys rapheidolabis* (Kiær 1915, pl. 1, fig. 6). As evidenced by the sections, there is a complete fusion between the posterior paranuchal and centronuchal plates, and everything goes to prove that this is true of all the other bones in the dermal skull-roof as well.

Immediately underneath the basal face of the exoskeleton there is a system of fairly thin, ramifying canals which throughout their extent are lined with delicate bone layers (plx_{scu}, pl. 1, fig. 1; see Kiær 1915, p. 12, pl. 1, figs. 1, 4). Some of those canals may have carried cutaneous nerve branches, but the great majority of them were surely vascular, forming a wide-spread plexus, the *subcutaneous vascular plexus*, which lay in the subcutaneous connective tissue just below the basal boundary of the corium or, in some places at least, in the very perichondrium on the dorsal side of the endocranium. Despite their position, however, the vascular canals of this plexus show a distinct radiating arrangement which is to some extent coincident with that of the vascular canals in the middle layer of the dermal bones above. A corresponding distribution of the subcutaneous vascular canals is sometimes traceable on the dorsal side of the head in other Arthrodires as well, e.g. in certain *Dolichothoraci* (*Arctolepida*) from the Wood Bay Series of Spitsbergen at my disposal (*Actinolepis ?*, fig. 6). The significance of this will be dealt with in another connection.

Lateral line canal system. The lateral line canals are comparatively wide and occupy a similar deep position in the exoskeleton as in other *Petalichthyida* (see Stensiö 1925, *c. pp*, *ifc*, *l.c. soc*, figs. 4, 8, 9, 16), and they open externally with single rows of pores, situated on their lateral side (*po*, pl. 1, figs. 1, 5, 6; Kiær 1915, p. 12). Along the cephalic division of the main lateral line (*lc*, pl.

1, fig. 1) the pores are round and placed fairly close together, and the tubes leading up to them are mostly separated from each other all the way from their points of issue from the lateral line canal to the external face of the exoskeleton (*po*, *tu*, pl. 1, fig. 6). Along the supraorbital and posterior pit-line canals (*soc*, *pp*, pl. 1, fig. 1), on the other hand, the pores are developed as narrow slits with their long axes parallel to that of the canals, and the tubes leading to them from below are not always clearly distinguishable from each other except close underneath the external face of the exoskeleton (*po*, *tu*, pl. 1, figs. 1, 5). Some of the pores and tubes belonging to the posterior pit-line canals are so indistinctly bounded off from each other that, in some places at least, those canals tend to open to the exterior with a continuous narrow slit similar to that of the lateral line canals in certain *Dolichothoraci* (see Stensiö 1925, fig. 22, Gross 1940, fig. 12D). A similar tendency is noticeable in *Notopetalichthys* where, if I understand Woodward (1941, p. 95) and White (1952, p. 283) correctly, the lateral line canals pass over into open lateral line grooves near the rostral and lateral margins of the skull-roof.

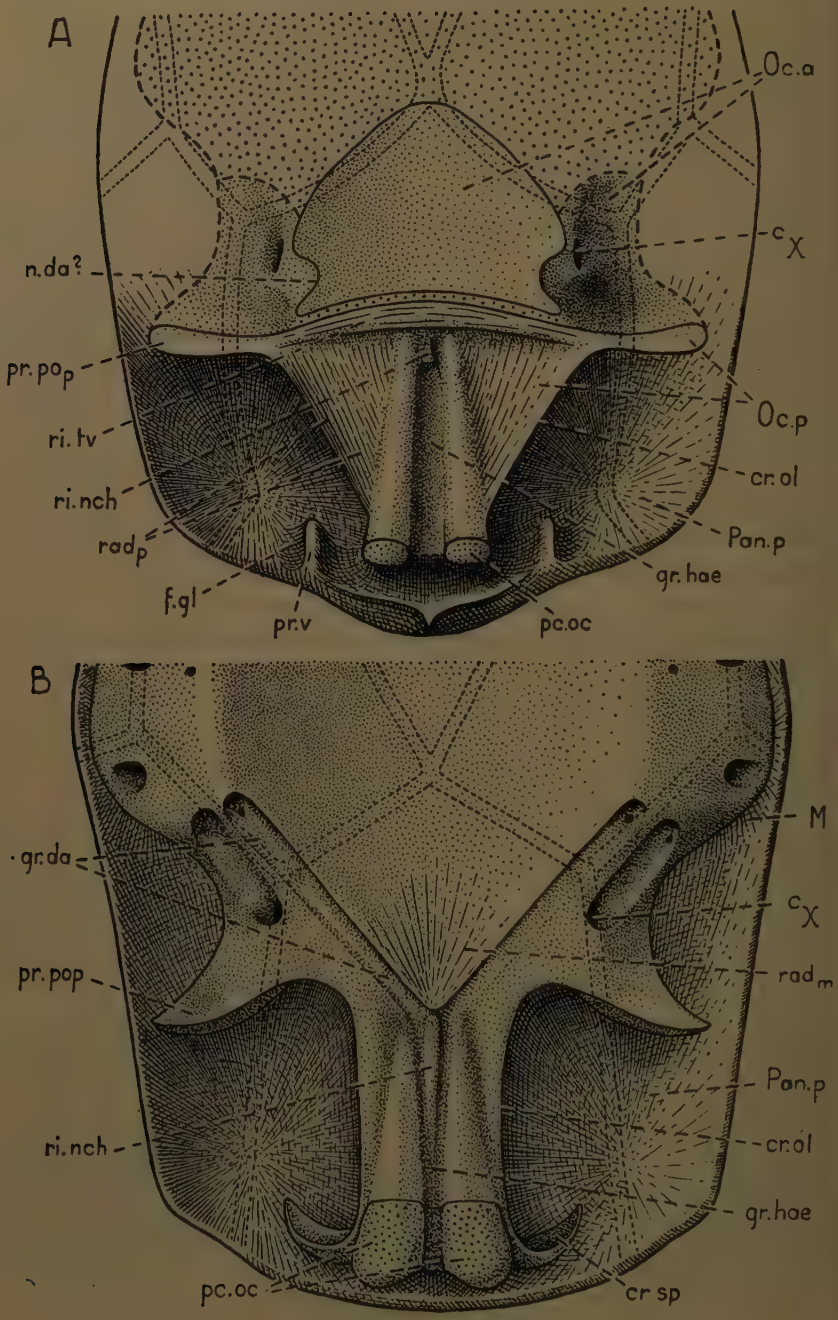
Except in some insignificant details, the course of the lateral line canals is as reconstructed by Kiær (fig. 5 F; see Kiær 1915, fig. 2 d). It may be mentioned, however, that from the material at my disposal, I have been unable either to confirm or disprove Kiær's contention that the most posterior part of the cephalic division of the main lateral line is bent laterally at the radiation center of the posterior paranuchal plate. There are no traces of the system of lateral line canals representing, in part at least, the middle pit-line canal of other Arthrodires (*mp*, fig. 5 E), which was detected by White (1952, p. 283) in *Notopetalichthys*, and to my knowledge, such canals do not occur in *Macropetalichthys* or *Lunaspis* either.

Endoskeleton. To judge from the holotype, the endocranium was entirely cartilaginous in the ethmoidal, orbitotemporal and otic regions. In the occipital region, on the other hand, it exhibits two perichondral ossifications which are to some extent reminiscent of the anterior and posterior occipitals in *Leiosteus concavus* Gross (see Stensiö 1934, pp. 37–43, *Oc*, *Syn*, fig. 20, pl. 6, fig. 3, pl. 8, fig. 4, pl. 9, fig. 1), and may be referred to here under the same names as the latter (*Oc. a*, *Oc. p*, fig. 7A, pl. 1, figs. 3, 4). As evidenced by those ossifications, the occipital region of the endocranium is fundamentally as in *Macropetalichthys* and *Epipetalichthys* where its general structure is concerned. In shape and proportions, however, it is distinguishable from the corresponding region of the endocranium in both these forms (fig. 7 A, B; Stensiö 1925, fig. 18).

The anterior occipital consists of (a) a plane, roughly heart-shaped, median part on the basal face of the anterior, broad division of the occipital region, and (b) a paired lateral part on the lateral faces of this division (*Oc*, *a*, fig. 7 A, pl. 1, figs. 3, 4). On each side the median part shows a distinct postero-lateral notch (*n. da?*, fig. 7 A, pl. 1, figs. 3, 4) which, to judge from the condition of *Macropetalichthys* and *Epipetalichthys* (*gr. da*, fig. 7 B; see Stensiö 1925, figs. 1, 6, 18) was developed for the radix aorta. Laterally, and a little anteriorly to this notch, each lateral part of the ossification is pierced by an opening for a canal, forwardly and outwardly directed, which in all probability transmitted the n. vagus (*c*$_x$, fig 7 A, pl. 1, fig. 4).

In the posterior occipital one may distinguish two parts, viz. (a) a very short anterior part which consists of the posterior postorbital process of each side and a fairly thick transverse ridge connecting those processes with each other straight across the ventral face of the endocranium (*pr. po*$_p$, *ri. tv*, fig. 7 A, pl. 1, figs. 3, 4), and (b) a much longer posterior part which occupies a position on the posterior, narrow division of the occipital region and gradually decreases in breadth in a caudal direction (fig. 7 A, pl. 1, figs. 3, 4). In ventral view, the latter part of the ossification is roughly triangular, and on each side it is bounded off by a sharp crista occipitalis lateralis which projects laterally and a little ventrally (*cr. ol*, fig. 7 A, pl. 1, figs, 3, 4). There is every reason to believe that, as in *Macropetalichthys* (Stensiö 1925, *cr. od*, figs. 2, 3, 5, 16), it is also provided with a median crista occipitalis dorsalis in its dorsal part (which cannot be studied in detail in the holotype).

On the ventral face of the posterior occipital, immediately behind the transverse ridge between the posterior postorbital processes referred to above, there is a short, median notochordal ridge, from which a fairly wide and deep haemal groove extends backwards right to the posterior end of the ossification (*ri. nch*, *gr. hae*, fig. 7 A, pl. 1, figs. 3,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4; cf. fig. 7 B, and Stensiö 1925, *hæm*, figs. 2, 17, 18; Stetson 1930, *hg*, fig. 3). In addition to the notochord (which lay in, or near, its dorsal roof), this groove, in part at least, also contained the anterior part of the unpaired aorta dorsalis (cf. in *Macropetalichthys*, Stensiö op. cit., pp. 96, 110). The posterior occipital is not connected with the dermal skull-roof by means of craniospinal processes similar to those in *Macropetalichthys rapheidolabis* (*cr. sp*, fig. 7 B), and as far as I can find, it shows no openings for spino-occipital nerves. Like in *Macropetalichthys* and *Epipetalichthys*, the most posterior part of the occipital region, which articulated against the vertebral column, was entirely cartilaginous (*pc. oc*, fig. 7).

The perichondral bone of the anterior occipital is very thin throughout its extent, and it shows no traces of a radiating structure. On the ventral face of the posterior occipital, on the other hand, this bone is comparatively thick, containing numerous vascular canals which are highly reminiscent of those in the middle layer of the dermal bones in that they are fairly wide and separated from each other by thin bony trabeculae. On each side of the haemal groove, these canals radiate forwards and outwards from a center lying at the very posterior border of the perichondral bone (*rad_p*, fig. 7 A). Further anteriorly, in the transverse ridge near the anterior border of the posterior occipital (*ri. tv*, fig. 7 A, pl. 1, figs. 3, 4), there may be vestiges of a median

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Fig. 7. Restorations of the posterior part of the endocranium and its relation to the dermal skull-roof in two representatives of the *Petalichthyida*. Ventral view. The course of the lateral line canals in the skull-roof indicated by double interrupted lines. Cartilage dotted. *A*, *Ellopetalichthys scheii* (KIÆR), based on the holotype; x 2.5. B, *Macropetalichthys rapheidolabis* NORWOOD & OWEN, compiled from Stensiö 1925, figs. 1, 15. The latter figure is drawn to such a scale that the length of the dermal skull-roof is the same as in *A*.

M, marginal plate; *Oc.a*, *Oc.p*, anterior and posterior occipitals; *Pan.p*, posterior paranuchal plate.

cr.ol, crista occipitalis lateralis, *cr.sp*, cranio-spinal process; c_x, opening for the n.vagus; *f.gl*, glenoid fossa; *gr.da*, groove for the radix aorta; *gr.hae*, haemal groove; *n. da?*, notch for the radix aorta; *pc.oc*, cartilage in the most posterior part of the occipital region; *$pr.po_p$*, posterior postorbital process; *pr. v*, ventral process of the posterior paranuchal plate; *rad_m*, *rad_p*, unpaired median, and paired posterior, radiation center of the perichondral bone of the occipital region, respectively; *ri. nch*, notochordal ridge; *ri. tv*, transverse ridge of the posterior occipital.

radiation center, corresponding to that which, in *Macropetalichthys*, lies about at the transition between the anterior and posterior divisions of the occipital region (*rad*$_m$, fig. 7 B).

As far as one can judge, the endocranial ossifications are entirely without bone or other hard tissues in their interior. Enchondral bone has previously been described both in *Macropetalichthys* and *Epipetalichthys* (Stensiö 1925, pp. 93, 154, pl. 31, fig. 2; Gross 1933 b, pp. 52–53, 1935, p. 29), and may well exist, to some extent at least, in both those forms. As far as *Epipetalichthys* is concerned, however, it is highly conceivable, in my opinion, that the bony trabeculae which extend for some distance in a basal direction from the bone layer lining the haemal groove and the notochordal space dorsally to that groove (Stensiö op. cit., pl. 31 fig. 2) were not originally situated in the cartilage of the endocranial wall, as maintained by Stensiö, but in the basal part of the perichondrium superficially to the cartilage. More precisely, those trabeculae, or at any rate the great majority of them, have such a shape and distribution that they very likely formed partition walls between vascular canals belonging to a particularly large intraperichondral vascular plexus in the basal part of the perichondral bone (cf. in *Dunkleosteus*, *can. i*, fig. 8 A, pl. 3). A corresponding, but not always quite so well-developed, vascular plexus is met with in the perichondral bone on the ventral face of the posterior part of the occipital region not only in *Ellopetalichthys scheii* (see above), but frequently also in *Macropetalichthys rapheidolabis* (the writer's observations on various specimens, particularly MCZ No. 1418). To what extent the «zart spongiösen Verknöcherungen des Endocraniums», which according to Gross (1935, p. 29), occupy a position immediately underneath the dermal skull-roof of *M. hoeninghausi*, lay in the endocranial cartilage, the perichondrium or the subcutaneous connective tissue between the perichondrium and the corium, cannot be decided at present.

* * *

The circumstance that in *Ellopetalichthys scheii*, presumably one of the youngest representatives of the *Petalichthyida* known so far, the endocranium is much less perichondrally ossified than in, for instance, *Macropetalichthys* may, as I have earlier suggested (Ørvig 1951, p. 412), be the result of a phyletic reduction of the endoskeletal hard tissues in this particular group of Euarthrodires. Another possibility, of course, is that the holotype of *E. scheii* is an immature individual where the endoskeleton had not yet reached the same degree of ossification as in the adult. For various reasons, however, I am inclined to believe that this specimen is not a juvenile one. The condition of the skull-roof (fusion of the dermal bones), for instance, seems to point in this direction. There may be some support for the view, therefore, that in the endocranium of *E. scheii*, the perichondral bone persisted only in the occipital region.

b. The endoskeletal hard tissues of *Dunkleosteus* LEHMAN and some other Pachyosteomorph Brachythoracids from the Ohio Shales formation.

In the large material of *Dunkleosteus*[1] [*D. intermedius* (NEWB.), *D. terrelli* (NEWB.), etc.] belonging to various museums in the U.S.A., endoskeletal ossifications are not infrequently met with, but these ossifications are still rather incompletely known with regard to their microstructure. According to Dunkle & Bungart (1942, p. 58), the anterior and posterior ossification in Meckel's cartilage (mentomandibular and articular) are made up of a cancellated bone tissue which cannot be distinguished histologically from that of the dermal bones. However, no figures were given by these writers showing the minute structure of this bone tissue, and from their descriptions one cannot gather whether it belongs to the perichondrium or to the cartilage underneath the perichondrium.

Endoskeletal ossifications are also met with in the North African material of *Dunkleosteus* described by Lehman (1956, pp. 39—40, *cap. n*, *cap. o*, pl. 2, fig. B, *R*, pl. 15, figs. A, B), but the hard tissue, or tissues, of those ossifications have not yet been investigated histologically.

For sectioning purposes I had at my disposal a specimen, presumably belonging to *Dunkleosteus terrelli* (AMNH No. 125 G, — Newberry Collection), which shows 3 contiguous fin radials perfectly similar to those earlier described by Newberry (1889, pp. 144–146, pl. 7, figs. 1, 1 b) and Heintz (1932, pp. 196–197, fig. 85). It cannot be decided at present whether the radials of this particular specimen belong to the paired, or unpaired, fins, but in any case it is clear that radials of the same kind occur both in the pectoral and pelvic fins of *Dunkleosteus* (cf. e.g. CNMH No. 5895; and Lehman 1956, p. 40, *R*, pl. 15, figs. A, B). The individual fin radials consisted originally of cartilage, lined except at their distal and proximal ends with a continuous, comparatively thick, layer of perichondral bone (Newberry 1889, p. 145; Lehman 1956, p. 40). The external face of this bone layer is somewhat rugose owing to the fact that throughout its extent it is densely pitted by the openings of wide vascular canals. There are no traces whatsoever of the subperichondral calcified cartilage or the interior mass of calcified cartilage which frequently occur in the endoskeletal ossifications of the head and shoulder girdle of Coccosteomorph Brachythoracids (*Plourdosteus*, *Coccosteus*, etc., see gcc_{sp},*gcc*, fig. 8 B; and Ørvig 1951, pp. 395–397, 405–407, gcc_{1}, *gcc*, figs. 15, 17, 18 B, pl. 4, figs. 1, 2, pl. 5, fig. 1). The fin radials are also entirely devoid of enchondral bone.

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[1] The generic name *Dunkleosteus* has recently been introduced by Lehman (1956, pp. 25–26) for the *Dinichthys* species belonging to the «*terrelli* group» (see Dunkle & Bungart 1946, pp. 5–7).

With regard to such structural details as lamination, distribution of cell-spaces and fibres, etc., the perichondral bone tissue (fig. 8 A, pl. 3) is reminiscent of that in *Plourdosteus canadensis* (WOODW.),[1] dealt with by the writer on an earlier occasion (Ørvig 1951, pp. 398–400, figs. 15 A, 16, pl. 4, fig. 1). It is easily distinguishable from the latter, however, by the fact it is unusually rich in vascular canals. In its basal part it contains a well developed vascular plexus, the *intra-perichondral vascular plexus*, consisting of 3–5, or even more, layers of canals. In each layer the canals, which are not infrequently lined with a few osteon lamellae, run mainly in two directions, either parallelly with the long axis of the radials, or concentrically around that axis (*can.* i_l, *can.* i_c, pl. 3). Quite a few of those canals, which open on the basal face of the perichondral bone layer, evidently transmitted vessels extending from the perichondrium into the cartilage underneath. This shows that, at least as far as *Dunkleosteus* is concerned, the cartilage was vascularized to a considerable degree or, in other words, that it was probably of another kind than that in adult Euselachians in general (concerning the cartilage of other Arthrodires as compared with that of the Elasmobranchs, see Ørvig 1951, p. 429).

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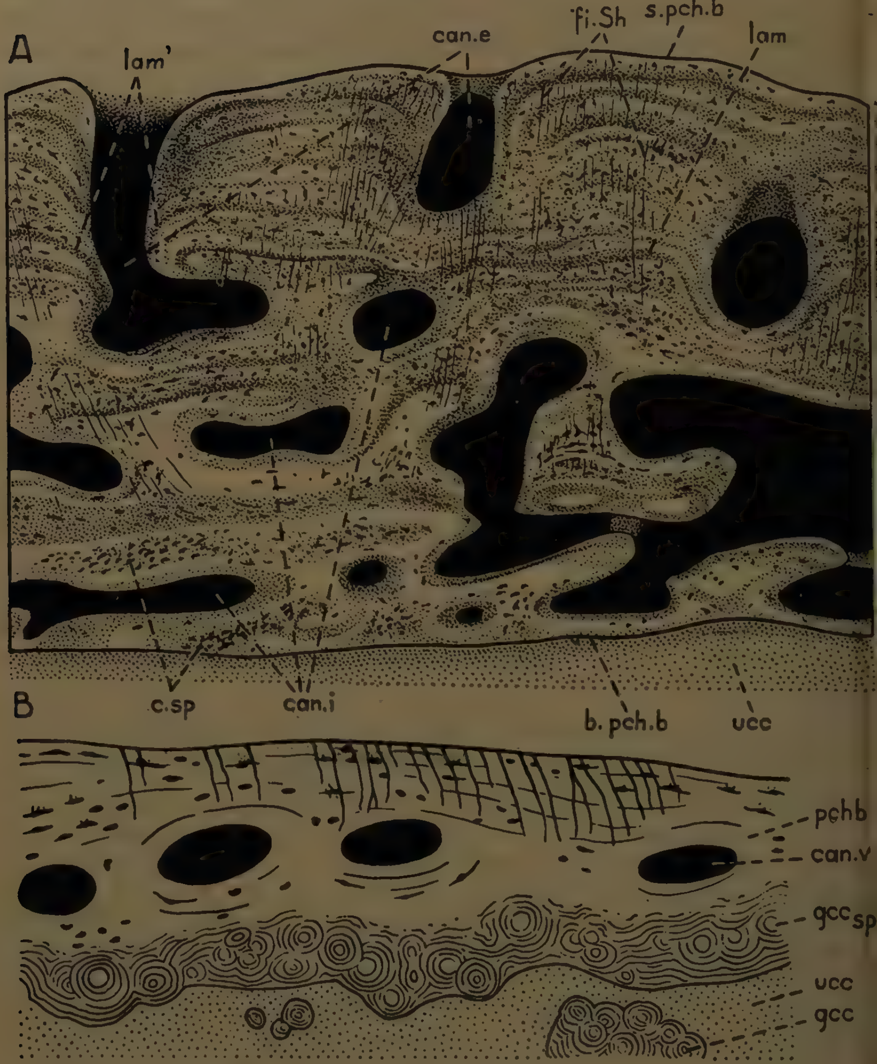
[1] The genus *Plourdosteus*, erected by the present writer in 1951 (p. 326), includes, in addition to the type species *P. canadensis* and other forms (see Ørvig 1957a, p. 373) also *P. trautscholdi* (EASTM.). The latter species was proposed by Eastman (1897b, pp. 35–36) for various fragmentary Coccosteomorph median dorsal plates from the Lower Upper Devonian of the River Syass section in Northwestern Russia (see also Eastman 1896, p. 222). These median dorsal plates were first described by Trautschold (1889, pp. 38–41, fig. on p. 40, pl. 5, figs. 1–6) together with several other bones of Arthrodires, Psammosteids and Crossopterygians under the collective name of *Coccosteus megalopteryx*, and by the same writer (Trautschold 1890, p. 576) they were later given a separate generic name, *Pelecyphorus*, but not referred to any particular species. From Trautschold's statements in the latter paper there can be no possibility whatsoever of confusing the *Pelecyphorus* median dorsals with the «Rückenschilder» of *Coccosteus obtusus* of his descriptions (Trautschold 1889, p. 44, pl. 5, figs. 7–9) which, as later investigations have shown, are the posterior median dorsal plates of an Antiarch, *Bothriolepis panderi* LAHUSEN (see further Gürich 1891; Eastman 1897b, pp. 35–36; Obrutchev 1931, pp. 287–290; Gross 1933a, p. 39; and others). Since *Pelecyphorus* is preoccupied and untenable, — a fact which was

In the superficial part of the perichondral bone a system of comparatively wide vascular canals, which are nowhere surrounded by osteon lamellae, extend with fairly regular interspaces from the intra-perichondral vascular plexus straight out towards the external face of the bone, where they open in a characteristic funnel-like manner (*can. e*, fig. 8 A, pl. 3). Originally those canals were traversed by vessels which in all probability connected the intraperichondral vascular plexus with another plexus, the *extraperichondral vascular plexus*, lying in the connective tissue above the external face of the perichondral bone. Near the margins of the canals the bone laminae show a

commented upon already by Eastman (1897b, p. 36), — it is merely an early synonym of *Plourdosteus*.

In one of his notes on piscine taxonomy, published a few weeks before my paper of 1951, Whitley (1951, p. 68) has proposed the new generic name *Phoebammon* for *Pelecyphorus* TRAUTSCHOLD. This raises the question whether, by rule of priority, *Plourdosteus* ØRVIG is to be replaced by *Phoebammon* WHITLEY. As the type species of *Phoebammon*, however, Whitley, who is obviously not familiar with the literature on Arthrodires, had choosen *Coccosteus obtusus* TRAUTSCHOLD which, as is evident from the above, has nothing to do with *Pelecyphorus* as defined by Trautschold (1890, p. 576). The conclusion must be, therefore, that *Plourdosteus* is not invalidated by *Phoebammon*, which is, in fact, a new (and unnecessary) synonym of *Bothriolepis* EICHWALD.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distinct inward bend (*lam'*, fig. 8 A, pl. 3). This circumstance proves, of course, that the canals had funnel-like openings also in earlier stages of growth and that they increased in length *pari passu* with the successive apposition of new bone laminae to the external face of the bone layer. In this, and in their other properties too, the ascending canals now under consideration bear a striking resemblance to those described by Gross (1934, pp. 529, 533) in the superficial part of the dermal bones of *Phyllolepis* (*can. asc*, fig. 9).

The fin radials of *Dunkleosteus* clearly grew in length by the formation of new cartilage at their proximal and distal ends, and in thickness by the successive apposition of new bone laminae to the external face of the perichondral bone layer. In full agreement with this is the fact that the perichondral bone frequently is a little thicker, proportionally, in the middle (oldest) part of the radials than it is near their ends. It is worth mentioning also that there are no signs of resorption or regeneration of hard tissue in the basal part of the perichondral bone adjoining the cartilage.

No sections could be made of the ossifications in the endocranium, visceral endoskeleton and endoskeletal pelvic girdle of *Dunkleosteus*, but an examination of those ossifications in a series of specimens clearly revealed that on those sides at any rate, where they are not attached to, or more intimately connected with, any of the dermal bones, they are lined with a layer of perichondral bone which in external aspect and in internal structure as well, is exactly like that in

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Fig. 8. *A*, *Dunkleosteus* cf. *terrelli* (Newb.). Upper Devonian, Ohio Shales formation. Section of the perichondral bone of a fin radial; Section No.S 1257; approximately x 50. *B*, *Plourdosteus canadensis* (Woodw.), Lower Upper Devonian, Escuminac Bay, P. Q., Canada. Section of the lining of perichondral bone and subperichondral calcified cartilage of the mentomandibular, somewhat altered from Ørvig 1951, fig. 15A; x 140.

b.pch.b, basal face of the perichondral bone; *can.e*, *can.i*, vascular canals in the superficial and basal parts of the perichondral bone, respectively; *can.v*, vascular canals; *c.sp.* cell-spaces; *fi.Sh*, canals for fibres of Sharpey; *gcc*, globular calcified cartilage; gcc_{sp}, subperichondral calcified layer; *lam*, lamination of the perichondral bone; *lam'*, inwardly bending lamination at the margins of the vascular canals in the superficial part of the perichondral bone; *pch.b*, perichondral bone, and *s.pch.b*, superficial face of this bone; *ucc*, matrix-filled spaces, originally occupied by uncalcified cartilage.

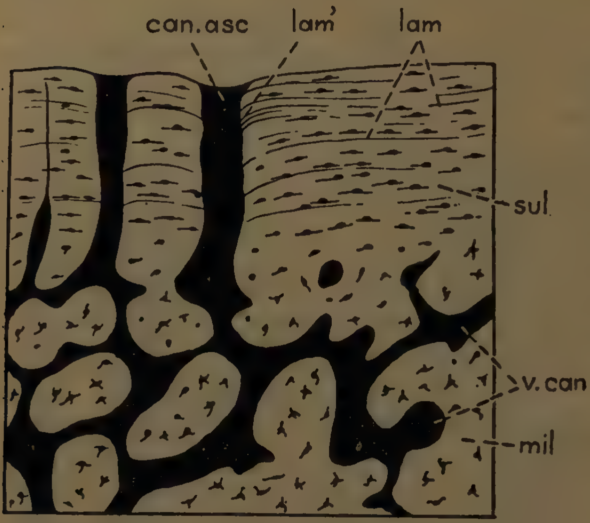

Fig. 9. *Phyllolepis* sp. Upper Devonian, North-western Russia. Vertical section of the superficial part of a dermal bone, from Gross 1934, fig. 1C; x 90. *can. asc*, vascular canals ascending from the middle layer to the external surface; *lam*, lamination of the superficial layer, and *lam'*, inward bend of this lamination at the margins of the ascending vascular canals; *mil*, *sul*, middle and superficial layers, respectively; *v.can*, vascular canals.

the fin radials referred to above. In addition, some at least, of those ossifications differ from the fin radials in that, as far as one can judge macroscopically, they exhibit a great many trabeculae of true enchondral bone in their interior. This system of bony trabeculae, which is rather suggestive of that in the middle, vascular layer of the dermal bones, is descernible e.g. in some of the ossifications in the ethmoidal region of the endocranium, the palatoquadrate and Meckel's cartilage which supported the dermal jaw elements (*D. terrelli*, USNM No. 21314; *D.* sp., CMNH No. 7568; various other specimens), and as far as I can find, it occurs also in the ossified parts of the pelvic girdle (which are particularly well displayed in *D.* sp., CMNH No. 5895). To what extent the cancellated bone tissue in the nasal capsules of *D. terrelli* (AMNH specimens; see Newberry 1889, pl. 7, figs. 2, 2 b; Stetson 1930, p. 26, pl. 6, fig. 3; Stensiö 1942, p. 23) formed in the cartilage or in the perichondrium externally to the cartilage, cannot be decided at present.

It may be gathered from the above that in their structure the endoskeletal ossifications of *Dunkleosteus* differ to some extent from those in other *Brachythoraci* and in the *Dolichothoraci* (*Arctolepida*) as well, more so, in fact, than I have previously had reason to believe (Ørvig 1951, pp. 407–408). In *Plourdosteus canadensis* (*v. can*, fig. 8 B; Ørvig op. cit., pp. 398–399, fig. 15 A, pl. 4, fig. 1), *Coccosteus decipiens* AG., several of the Wildungen *Brachythoraci*, *Buchanosteus murrumbidgeensis* WHITE (which I have had the opportunity to investigate thanks to the courtesy of Dr. E. I. White, London), *Kujdanowiaspis*, *Phlyctaenaspis acadica* (WHITEAVES), the Spitsbergen *Dolichothoraci* and other forms as well, the perichondral bone layer of the endoskeleton contains, as a rule, an intraperichondral vascular plexus in its basal, or middle, part («middle cellular layer», White 1952, p. 272), represented by a network of canals which may show varying degrees of complexity, but never, or at any rate rarely, attains similar proportions as in *Dunkleosteus*. Furthermore, the superficial part of the perichondral bone is generally penetrated more or less obliquely by irregularly distributed vascular canals, connecting the intraperichondral and extraperichondral vascular plexuses with each other, but in the great majority of the Euarthrodires just referred to, it never exhibits such a system of wide, parallel, vascular canals, crossing the bone-laminae at about right angles, as in *Dunkleosteus* (*can. e*, fig. 1 A, pl. 3), and in those forms where a similar canal system does occur, it is limited to certain, very restricted, parts of the endoskeleton only (in *Plourdosteus canadensis*, for instance, to the superficial part of the perichondral bone lining the nasal pits).

Another difference between the endoskeletal ossifications of the *Brachythoraci* and *Dolichothoraci* just referred to on the one hand, and those of *Dunkleosteus* on the other, is that the former are completely devoid of enchondral bone proper (Ørvig 1951, pp. 397, 407, 408–409, 436). Bone of this particular kind is known with certainty in some Rhenanid Arthrodires (*Asterosteus stenocephalus* NEWB., see Ørvig op. cit., p. 411), and it probably exists in other forms as well (concerning the *Petalichthyida*, see above), but in the Arthrodires in general there is, to my knowledge, no evidence that it has ever reached a similar degree of development as in *Dunkleosteus*. In *D. intermedius* and *D. terrelli* which, as is well known, were predatory fishes of particularly large size, it may seem reasonable to assume that by containing a mass of cancellated enchondral bone in their interior, the ossifications in the anterior part of the endocranium and in the palatoquadrate and Meckel's cartilage were especially adapted to withstand heavy mechanical stresses in connection with the biting movements of the powerful dermal jaw elements. However, it is certainly difficult, on mechanical grounds alone, to find an entirely satisfactory explanation for the fact that enchondral bone is represented e. g. in the ossified parts of the pelvic girdle of *Dunkleosteus*, but absent altogether in the fin radials, even in those of the pelvic fins. This seems to show that as in other Arthrodires, in *Dunkleosteus* the degree of lime-impregnation in the different parts of the endoskeleton was dependent not merely on mechanical, but also on a variety of other factors, some of which are not yet properly understood.

Apart from *Dunkleosteus*, I was able to examine, and in some few cases to section, endoskeletal ossifications of certain other Pachyosteomorph Brachythoracids from the Upper Devonian of Northeastern U.S.A. In *Diplognathus mirabilis* NEWB. (CMNH No. 7255, figured by Dunkle & Bungart 1943, fig. 1), *Heintzichthys* sp. (CMNH No. 5130) and presumably in other forms as well, those ossifications exhibit perichondral bone of much the same kind as in the Coccosteomorph and non-Dinichthyid Pachyosteomorph Brachythoracids. On the other hand, they seem always to be without calcified cartilage or bone in their interior.

c. The microstructure of the *Palaeomylus* tooth plates and of various Ichthyodorulites which may belong to the *Ptyctodontida*.

The *Ptyctodontida* were for a long time known by their isolated tooth plates only and, because of the special structure of those plates, they were, up to the beginning of this century, generally regarded as early representatives of the *Holocephali* (Newberry 1889; Woodward 1891; Rohon 1895; Eastman 1898; 1908; Dean 1906, and others). Since then, specimens have been detected in the German and Scottish Devonian displaying this particular kind of tooth plates together with exoskeletal elements of the head and shoulder girdle and/or endoskeletal ossifications (Jaekel 1906; 1927; p. 337; 1929; and other papers; Gross 1933 b; Watson 1934; 1938; Woodward 1939; etc.). This material, as is well known, has led to the conclusion that the *Ptyctodontida* are not Chimaeroids or any other sort of Bradyodonts, but a separate group of the Arthrodires.

The microstructure of the Ptyctodontid tooth plates has been dealt with in *Ptyctodus* PANDER (= *Aulacosteus* EICHW.) on several occasions, and in *Rhynchodus* NEWB. on some (Pander 1858, pp. 48–50, pl. 8, figs. 14–22, pl. 9; Rohon 1895, pp. 2–3, 8–10, pl. 1, figs. 3, 4; Hussakof & Bryant 1918, pl. 34, fig. 2, pl. 35; Thomasset 1930, pp. 70–72, fig. 30; Gorizdro—Kulczycka 1934, pp. 24–27, 29, 31, figs. 3, 4, pl. 1, figs. 4–6, pl. 2, figs. 1–3, pl. 3; Gross 1935, pp. 28–29, pl. 5, fig. 3)[1], but is still very incompletely known where *Palaeomylus* WOODW. is concerned, (see Wells 1944, p. 34, pl. 6, figs. 8, 9). The description given here of the hard tissues in the latter form is based mainly on a large, somewhat broken, tooth plate which presumably belongs to the lower jaw (AMNH-Specimen, without number).[2] This tooth plate, which is determined as *P. greenei* (NEWB.), is rather large and deep. Antero-dorso-medially it is produced into a fairly strong beak. Its biting area (tritoral face), which is comparatively broad just behind the beak, exhibits two rounded cusps, antero-medial and postero-lateral (see Newberry 1889, p. 51, and Hussakof & Bryant 1918, fig. 40), which in shape and position are highly reminiscent of those in *P. hussakofi* BRYANT (Hussakof & Bryant 1918, p. 122, pl. 41). The accompanying label gives no information concerning the locality or stratigraphical level of this tooth plate, but the state of preservation may indicate, however, that it comes from the Hamilton beds of Milwaukee, Wisc.

On its lateral and medial sides the tooth plate is coated with a fairly thin layer of hard tissue on whose shining external surface, as normally in the *Ptyctodontida*, concentric lines of growth are displayed. This layer consists of (a) an external part of pallial dentine (Ørvig 1951, pp. 332, 336), and (b) an internal part of ordinary osteodentine. The pallial dentine, which is nowhere covered superficially by enamel, or any enamel-like substance, is pierced by comparatively thin, about parallel, dentinal tubes which issue from a system of vascular canals on its internal side. The osteodentine is highly reminiscent of that in the teeth and fin spines of several other fishes, e.g. the Selachians, consisting of zones of interosteonal bony substance and of perfectly normal, well-developed, dentinal osteons (see Ørvig 1951, pp. 333–335).

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[1] In a new paper, published after the above was written, Gross (1957, pp. 26–32, 36–37, figs. 12–15) has given new descriptions of the tooth plates in *Ptyctodus* and *Rhynchodus*. The conclusions put forward in that paper with regard to the interpretation of the Ptyctodontid tooth plates, which are not in all respects identical with mine, will be discussed in another connection.

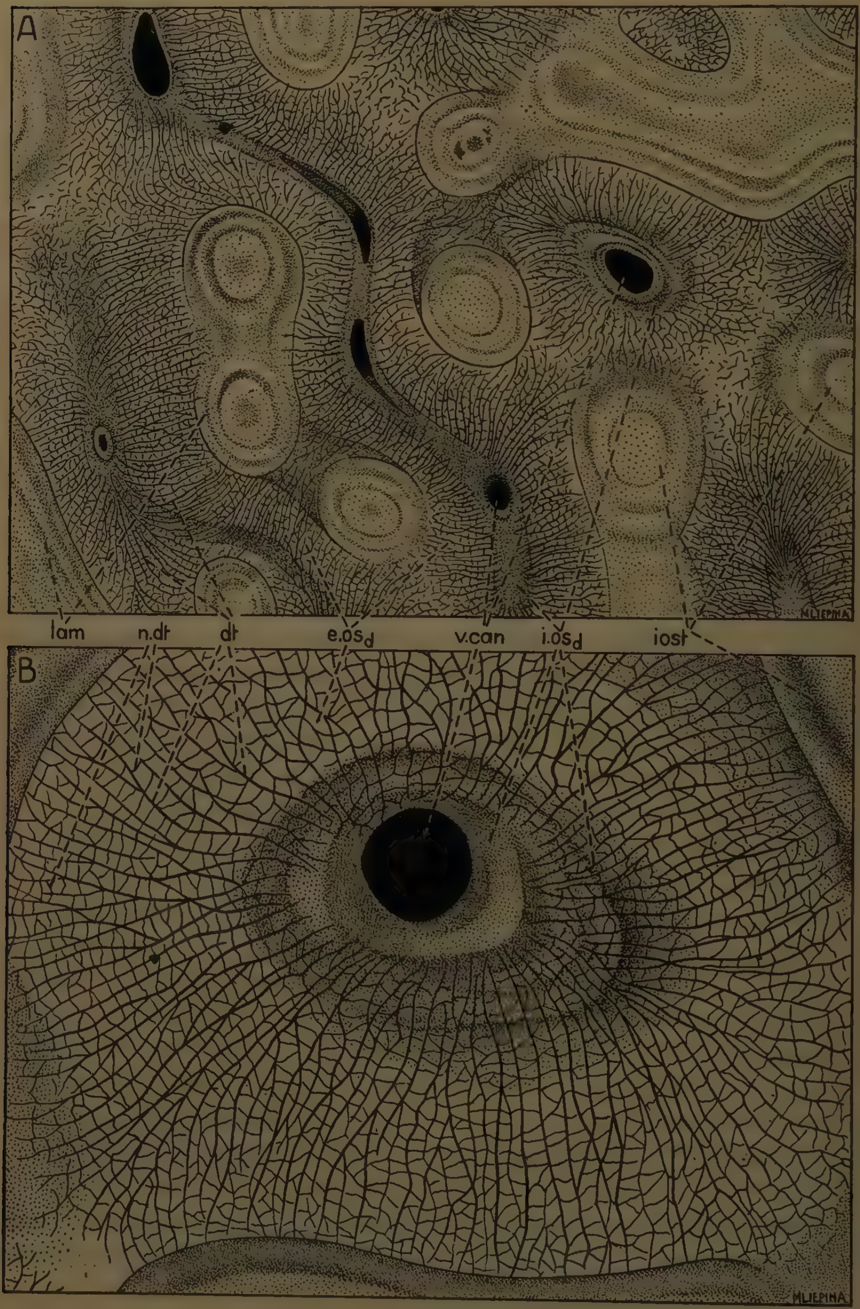
[2] With regard to its microstructure, this specimen is perfectly similar to another *Palaeomylus* tooth plate which I was able to investigate histologically thanks to the courtesy of Dr. J. T. Gregory of the Peabody Museum of Natural History. Yale University, New Haven, Conn. The latter tooth plate, which presumably is indeterminable as to species, comes from the New Albany Black Shale of Louisville, Ky.

In its interior the tooth plate is made up ot a trabecular hard tissue and of another dense, hard tissue which resembles osteodentine in many ways and, as for as one can judge, may actually be a special variety of the latter. The trabecular hard tissue, of which the main part of the tooth-plate is composed, is distinctly lamellated and is entirely without cell-spaces. It is evidently a genuine bone tissue which in many ways resembles that of the intervascular trabeculae in the interior of the teeth and fin spines of various Selachians (see Ørvig 1951, pp. 332, 336–337). In some respects, e.g. in its reaction between X nicols, it is also to some extent suggestive of the trabecular aspidin in the middle vascular layer of the exoskeleton of various *Drepanaspida* e.g. *Psammolepis*, and several other *Heterostraci* as well. Trabecular bony tissue is also met with in the basal part of the tooth plates of *Ptyctodus* and *Rhynchodus* (see e.g. Gorizdro–Kulczycka 1934, pl. 2, figs. 1, 3, pl. 3 fig. 5).

The osteodentine-like hard tissue in the interior of the tooth plate is distributed so as to form 3 separate columns (*dentigenous columns* or *tritoral columns*), fairly short and thick, which ascend more or less vertically from below towards the biting area. One of those columns, the *symphysial tritoral column*, extends upwards into the anterior beak, close to, and parallel with, the symphysial margin. The positions of the other two columns, referred to here as the *antero-medial* and *postero-lateral tritoral column*, respectively, are marked out by the cusps on the biting area mentioned above (see Hussakof & Bryant 1918, pl. 41, fig. 2). More precisely, each of those cusps represents, in fact, the most superficial part of a column which is raised somewhat above the level of the biting area. All tritoral columns are situated so that on one side (antero-medially in the symphysial column, medially in the antero-medial column, and laterally in the postero-lateral column) they are in contact with the external layer of pallial dentine and ordinary osteodentine already referred to. On all other sides, and basally, they are bounded off by the trabecular bony tissue dealt with above.

The osteodentine-like hard tissue of the tritoral columns is rich in vascular canals (*v. can*, fig. 10. pl. 4) which, in some places, tend to be about parallel with the long (vertical) axis of the columns, but elsewhere are more irregularly distributed. Throughout their extent, these canals are surrounded by well-defined systems of circumvascular dentine which presumably represent dentinal osteons of some sort, allthough they are not in all respects comparable to those osteons in the dentine of Selachians and Teleostomian fishes. Thus, in each system of circumvascular dentine, it is only the innermost, narrow portion, lining the vascular canal (*i.* os_d, fig. 10, pl. 4, fig. 2) that shows the same concentric lamellation and optical properties as a true dentinal osteon (see Ørvig 1951, pp. 334–335, os_d, pl. 3, figs. 1, 2, 6–8), whereas the outer, broad, portion (*e.*os_d, fig. 10, pl. 4) is made up of a peculiar, translucent substance with, because of its homogenous, non-lamellated structure and the very low birefringence it exhibits in polarized light, (pl. 4, fig. 2) probably has no real equivalent in the dentinal osteons proper of other lower vertebrates, at any rate not in those of most non-Teleostomian fishes. In *Ptyctodus* and *Rhynchodus*, the systems of circumvascular dentine in the dense hard tissue at, or basally to, the biting areas (tritoral faces) of the tooth-plates consists of much the same special substance as in *Palaeomylus*.

The systems of circumvascular dentine are without cell-spaces similar to the odontoblast-spaces in the semidentine of several other groups of Arthrodires (see ØRVIG 1958). They are pierced by a great many, very thin dentinal tubes, situated close together, which issue in a radiating manner from the vascular canals (*dt*, fig. 10). The tubes are in communication with each other by numerous, short side-twigs, and together with those twigs they form a fine-meshed, reticular network (*n.dt*, fig. 10 B). As far as one can judge from the photomicrograph figured by Hussakof & Bryant (1918, pl. 35, fig. 2), dentinal tubes of this very characteristic kind are, presumably, also met with in the circumvascular dentine in the interior of the tooth-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plates described by these writers under the name of *Ptyctodus howlandi*. In *Ptyctodus calceolus* Newb. & Worthen from the State Quarry Limestone of Iowa (*dt*, fig. 11), however, and in all probability also in the other Ptyctodontid tooth-plates which have been investigated histologically so far (Pander 1858, pl. 9, figs. 10–13; Gorizdro–Kulczycka 1934, figs. 3, 4 a, pl. 1, fig. 5; and others), this dentine exhibits dentinal tubes which in their shape and distribution are more reminiscent of those in the osteodentine of other fishes, particularly of various Elasmobranchs.

The circumvascular dentine surrounding the individual vascular canals is separated from that of the contiguous canals by fairly broad, well marked-off, zones of acellular[1] bone tissue (*iost*, fig. 10, pl. 4). Since in their arrangement and structure those interstitial zones are indistinguishable from the bony trabeculae filling up the main part of the interior of the tooth plate, they no doubt correspond to the latter. Everything goes to prove, therefore, that the osteodentine-like hard tissue of the tooth-plates arose ontogenetically in the same way as osteodentine proper (see Ørvig 1951, pp. 332–333, 336–337, 347, 434), namely by the deposition of circumvascular dentine on the margins of a system of bony trabeculae which are not resorbed but persist unchanged also in the fully developed hard tissue. This is very probably true also of the similar hard tissue at, and basally to, the biting areas of the tooth plates in the other *Ptyctodontida* (the «tritor» in the terminology of many previous writers).

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[1] The term «acellular bone tissue», which is here adopted from Enlow & Brown (1956, p. 410), means any kind of bone tissue where enclosed cells, or cell-spaces, are absent.

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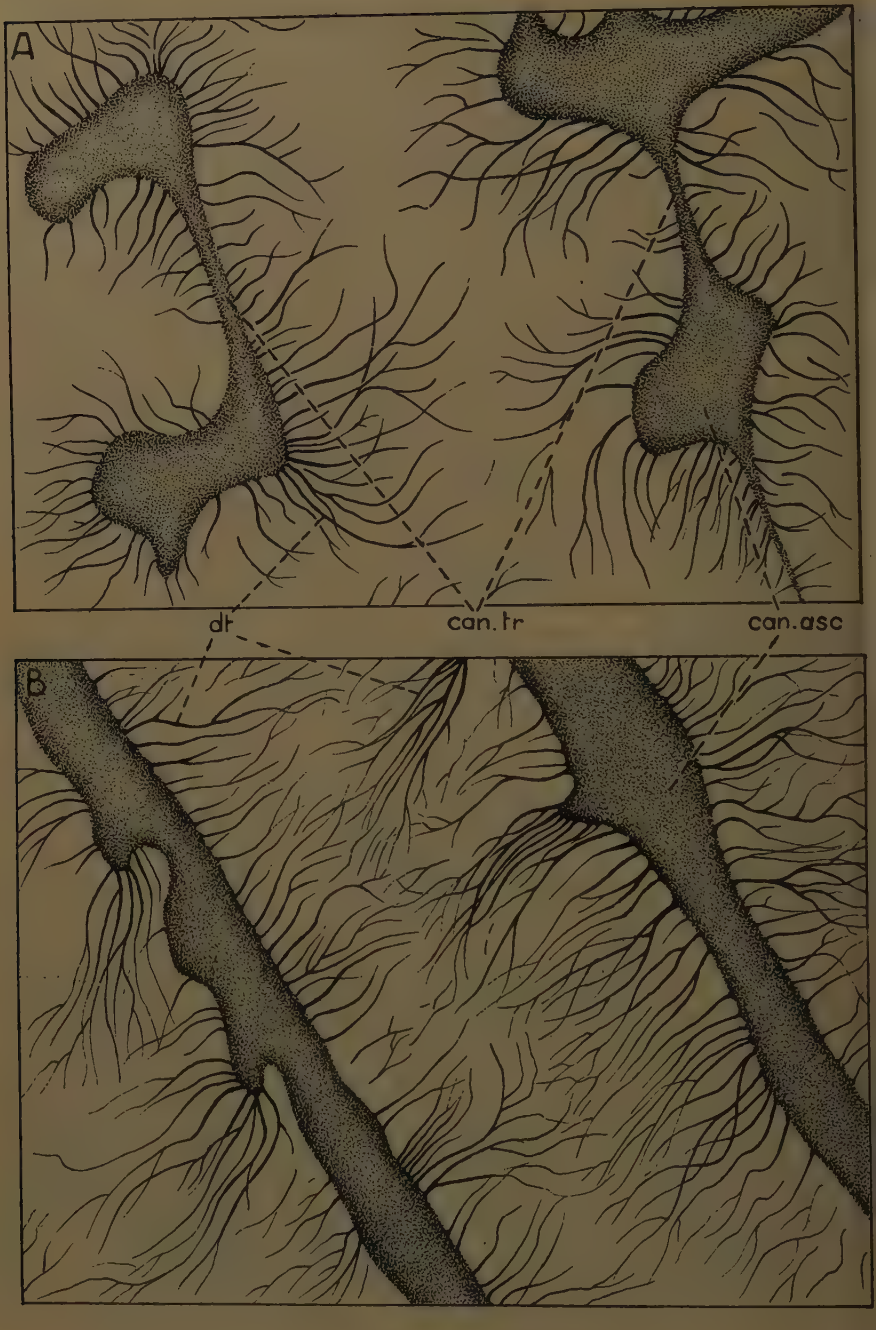
Fig. 10. *Palaeomylus greenei* (Newb.). Tooth plate, Devonian of the U. S. A., locality and stratigraphical level unknown. *A*, section of the osteodentine-like hard tissue in the symphysial tritoral column, cut about perpendicularly to the long (vertical) axis of that column. Section No. S 1268; x 100. *B*, more highly magnified detail of a system of circumvascular dentine in this hard tissue. Same section as *A*; x 335.

dt, dentinal tubes; $e.os_d$, $i.os_d$, outer and inner portions of the circumvascular dentine, respectively; *iost*, interstitial zones of bony tissue separating the systems of circumvascular dentine from each other, and *lam*, concentric lamellation of this bony tissue; *n.dt*, short side-twigs of the dentinal tubes; *v.can*, vascular canals.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As in *Ptyctodus* and *Rhynchodus*, the tooth plate no doubt grew continuously by the successive formation of hard tissue in its basal part. During the adult stages of this growth, the apposition of new osteodentine-like hard tissue to the basal part of the individual tritoral columns in all probability went on *pari passu* with the abration of the superficial part of those columns on the biting area.

The *Palaemylus* tooth plate dealt with here is clearly reminiscent of those in the other *Ptyctodontida*, particularly *Ptyctodus* and *Rhynchodus*, where its histological structure and mode of growth are concerned. On the other hand, it is also of a type of its own in that, instead of a continuous, elongated mass of osteodentine-like hard tissue in its superficial part as in *Ptyctodus* and *Rhynchodus* (the «tritor»), it contains 3 separate columns of this hard tissue which are nowhere in contact with each other. In this respect it is more suggestive of the tooth plates of various Mesozoic and Cenozoic *Holocephali* (*Ischyodus*, *Edaphodon*, etc.) than what are those of the other *Ptyctodontida*. In *Palaemylus* we are, in point of fact, concerned with the same kind of highly specialized, compound tooth plates as in the representatives of the *Holocephali* just referred to, — a kind of tooth plates, that is to say, which has arisen phyletically by the complete fusion of the consecutive generations of individual jaw-teeth existing in the dentition of the ancentral forms, and the further concentration of those fused tooth-generations into a series of tritoral columns. For several reasons which will be more fully discussed on a future occasion (in the 2nd part of my «Histologic studies of Placoderms and fossil Elasmobranchs»), this particular kind of tooth plates has clearly evolved quite independently in the predecessors of *Palaemylus* on the one hand, and the early Bradyodonts from which the *Holocephali* are derived on the other. This is evident above all from the point of view of histology, for although the hard tissue of the tritoral columns in the *Palaeomylus* tooth plates is in some ways different from ordinary

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Fig. 11. *Ptyctodus calceolus* NEWB. & WORTHEN. Lower Upper Devonian, State Quarry Limestone, Iowa. Sections of the osteodentine-like hard tissue at, and basally to, the biting area (tritoral face) of a tooth plate, cut (*A*) obliquely to, and (*B*), parallelly with the system of ascending vascular canals in this hard tissue. *A*, Section No. S 881, x 200; *B*, Section No. S 880, x 200.

can.asc, ascending vascular canals, and *can.tr*, thin transverse canals connecting them with each other; *dt*, dentinal tubes.

osteodentine (cf. above), it cannot possibly have any affinity whatever to, or be any sort of forerunner of, the peculiar tubular dentine of the corresponding columns in the Chimaeroid tooth plates which, as everything goes to show, is a hard tissue *sui generis*, consisting of dentinal osteons separated from each other by an interstitial substance not unlike enamel (see Ørvig 1951, pp. 342, 349; and the references cited there).

It may be mentioned here, finally, that the tooth plates of various Brachythoracid Arthrodires (*Mylostoma*, *Plourdosteus*, etc.), which will be dealt with in the 2nd part of my «Histologic studies» just referred to, are similar in many ways to those of *Palaeomylus* where their plan of construction is concerned, but clearly distinguishable from the latter by the fact that their tritoral columns are not made up of dentine proper, but of a more primitive dentinous tissue (semidentine).

* * *

In North America, several Middle and Upper Devonian deposits (as, e.g., the Delaware formation of Ohio, the Cedar Valley and State Quarry Limestones of Iowa, the Hamilton beds of Milwaukee, Wisc., the basal Conodont bed of the Genesee Group of New York, etc.) have yielded numerous Ptyctodontid tooth plates of various types, but to judge from the published accounts, none showing any of those tooth plates in their natural association with other parts of the exoskeleton. In a series of papers Eastman (1898, pp. 550–556; 1907, p. 73; 1908, pp. 131, 139, 142–143, 144; 1917, p. 244; see also Dean 1906, p. 136; Hussakof & Bryant 1918, p. 102) suggested that certain Ichthyodorulites such as *Eczematolepis* MILLER (syn. *Acantholepis* NEWB. and *Phlyctaenacanthus* EASTM., cf. Hussakof & Bryant, loc. cit.) and *Gamphacanthus* MILLER (*Heteracanthus* NEWB.), which frequently occur in the same beds as the tooth plates just referred to, may actually belong to the same animals as the latter.[1] In the

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[1] From the Upper Devonian of Iowa Eastman (1908, pp. 147–148, pl. 12, fig. 16) also described an ossified vertebral centrum which, as he suggested, may either beong to *Ptyctodus*, or to a contemporary Ptyctodontid. This centrum, however, is clearly similar to those which are now known to occur in various Devonian *Dipnoi* (Jarvik 1952, pp. 41–48, figs. 16–18, 20, 21, pl. 8) and surely belongs to a representative of that group of fishes. In the *Ptyctodontida*, as evidenced by the condition of *Chelyophorus* and *Rhamphodopsis*

2nd edition of his «Vertebrate paleontology» Romer (1945, p. 575) even listed *Palaeomylus* as a synonym of *Eczematolepis* (see also Hussakof & Bryant 1918, p. 102). Neither Eastman, nor any of the subsequent writers, however, have attempted to find out whether there is such a similarity in histological structure between those Ichthyodorulites and tooth plates as one might expect if they are really closely related to each other. The following brief observations on *Eczematolepis* and *Gamphacanthus* have been made with this particular problem in mind.

(1) The dermal bones referred to under the name of *Eczematolepis* from the Columbus and Delaware formations of Ohio, the Hamilton beds of Milwaukee, Wisc., etc., are mostly fairly thin and bear an ornamentation of small, low tubercles, situated close together (Newberry 1889, pl. 31, figs. 5, 5 a; Eastman 1898, p. 551; Teller 1906; and others). In two AMNH-specimens of *E. fragilis* (NEWB.) which I had the opportunity to section (Nos. 4529 G, — Newberry Collection, from the Ohio Bone Beds, and 3452 from the Delaware Limestone of Ohio), the microstructure is the following (Sections Nos. S 1288–1290). The ornamental tubercles are made up of typical dentine without scleroblast-spaces of any kind, penetrated by numerous, very thin dentinal tubes which are suggestive in many ways of those in, for instance, the *Machaeracanthus* spines (Wells 1944, p. 31; Ørvig 1951, fig. 2 A, B) and the *Palaeomylus* tooth plate dealt with above (*dt*, fig. 10, pl. 4, fig. 1), more so, in fact, than of those frequently met with in the early Elasmobranchs and *Ptyctodus* and *Rhynchodus* as well (cf. *dt*, fig. 11). These tubes issue upwards and outwards from a system of vascular canals lying entirely below the dentine. The tubercles are not coated externally by enamel or any enamel-like substance. Underneath the superficial tubercle layer the plates consist of a trabecular bony tissue without cell-spaces which is not essentially different from that in the exoskeleton of various Elasmobranchiomorph fishes, e.g. in the basal part of the teeth and spines of some Selachians, in the jawbones of certain Acanthodians (*Atopacanthus* etc., cf. fig. 15, pl. 5, fig. 1), and in the interior of the *Palaeomylus* tooth plates (p.322).

(Eichwald 1860, pl. 57, fig. 3; Watson 1938; Woodward 1939; Holmgren 1942, p. 216, fig. 36B), the vertebral column is entirely without centra of any kind.

The evidence concerning the taxonomic affinities of the *Eczematolepis* plates may be briefly summarized as follows. In view of their shape, ornamentation and other external characters (as revealed particularly in a series of ANMH- and USNM-specimens), it is conceivable, in my opinion, that those plates are referable to the Arthrodires. Some of them, at least, may well represent detached elements of a rather high and short exoskeletal shoulder girdle more or less similar to that of, for instance, the *Acanthothoraci*, or *Rhamphodopsis* and *Rhynchodus tetrodon* JAEKEL amongst the *Ptyctodontida* (fig. 12 C, D). The histological structure of those plates shows rather conclusively that they cannot very well belong to the *Brachythoraci*, *Dolichothoraci*, *Petalichthyida*, *Acanthothoraci*, *Phyllolepida*, *Rhenanida* or *Antiarchi* where, according to previous investigations and various unpublished observations of my own, the exoskeleton is always made up of semidentine (a dentinous tissue differing from dentine proper in that it contains scleroblast-spaces in addition to dentinal tubes, see Ørvig 1951, p. 348, fig. 2 E; 1958) and/or bone in its superficial part, and elsewhere of bone tissue exhibiting perfectly normal cell-spaces.[1] In the *Radotinida* and *Stegoselachii* the dermal bones have not been studied histologically so far, but it is very unlikely, for several reasons, that *Eczematolepis* can have anything to do with either of those groups. In the Arthrodires in general, as far as is now known, exoskeletal elements consisting of much the same dentine and acellular bone tissue as in *Eczematolepis* are only met with in some, at least, of the *Ptyctodontida*. From the point of view of histology, therefore, there may be reason to believe that the *Eczematolepis* plates belong to a representative of this group, most probably to the same one which possessed tooth plates of the *Palaeomylus* kind (this, at any rate, is indicated by the circumstance referred to above, that with regard to the structure of their hard tissues, particularly the dentine, the *Eczematolepis* plates are more reminiscent of the *Palaeomylus* tooth plates than of those in most species of *Ptyctodus* and *Rhynchodus*).

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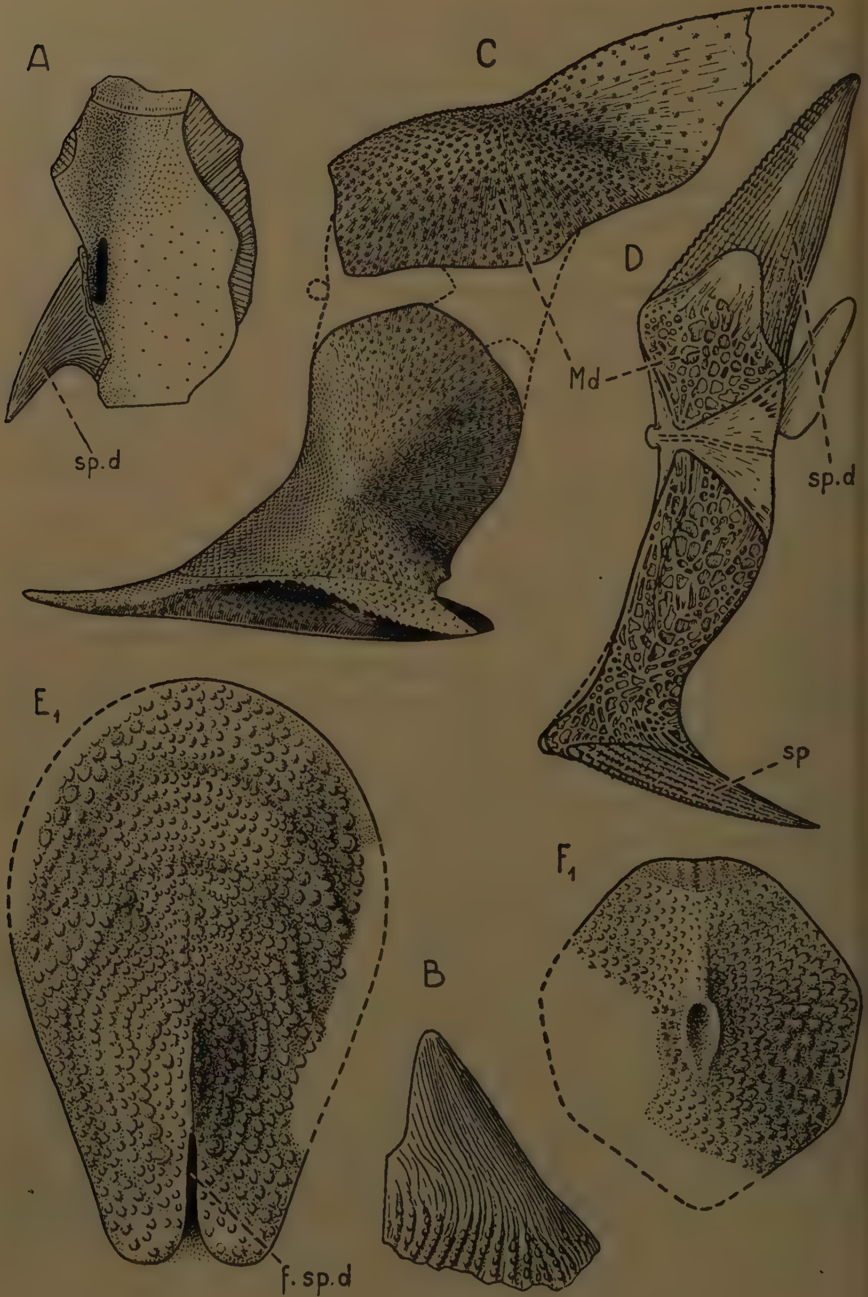
[1] For the same reason *Eczematolepis* cannot be related to the *Ohioaspis* plates from the Ohio Bone Beds (cf. Wells 1944, p. 16) which, because of their shape and microstructure (Ørvig 1958), very probably pertain to a Rhenanid Arthrodire (*Asterosteus?*).

(2) The *Gamphacanthus* spines from such Middle Devonian deposits as the Cedar Valley Limestone of Iowa and Illinois and the Hamilton beds of Milwaukee, Wisc., and the Upper Devonian Portage Shale of New York have attracted attention because of their peculiar ornamentation, consisting of flat, mostly rather broad, longitudinal ridges which are situated close together and frequently exhibit a distinct crenulation at their margins (Newberry 1889, pp. 65–66, pl. 21, figs. 4, 4 a, 5; Lindahl 1897, pl. 6; Eastman 1908, pp. 138–140; 1917, p. 245, pl. 1; Hussakof & Bryant 1918, p. 164, pl. 52, fig. 1). The following remarks on the microstructure of those spines are based on a MCZ-specimen of *G. politus* (Newb.) from the Cedar Valley Limestone of Iowa (St. John Collection, without number). Another specimen of the same species which I was able to section (AMNH No. 7964, — Teller Collection, from the Hamilton of Milwaukee) was too badly preserved to show any histological details of interest.

The ornamental ridges of the spines are made up of true dentine, not unlike that in, for instance, the tubercles of *Hybosteus mirabilis* (Gross) from the Guaja (Oredesch) beds of the Baltic Upper Middle Devonian (Gross 1930, pl. 5, figs. 20, 21), containing a system of ascending and anastomozing vascular canals which send off ramified dentinal tubes in all directions (*v. can*, *dt*, fig. 13 A, C). Underneath the dentine of the ridges the spines consist of a hard tissue which closely resembles bone, and presumably may be referred to as such. This hard tissue, which is penetrated by fairly wide, irregularly distributed vascular canals, exhibits cell-spaces which are particularly numerous in its innermost part, and in some places it also contains cell-canaliculi, somewhat suggestive of short, branching dentinal tubes, which issue in a radiating manner from the vascular canals (*c. sp*, *dtc*, *v. can*, fig. 13 A, B). In polarized light it shows the same reaction as fairly coarse-fibred «Faserknochen», but a slight osteon development is also discernible around some of the vascular canals.

On the basis of what is now known concerning their shape, ornamentation and microstructure, the *Gamphacanthus* spines cannot be determined with full certainty as to their systematic position. In some of their external characters they are more or less suggestive of the fin spines of various early Elasmobranchs (e. g. *Ctenacanthus* and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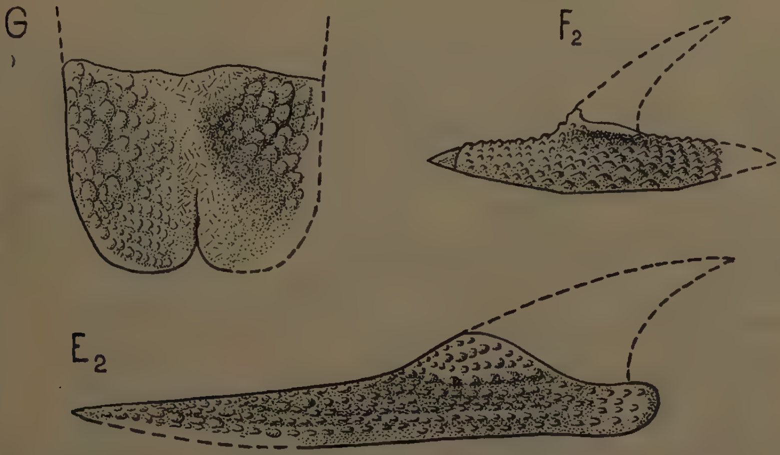
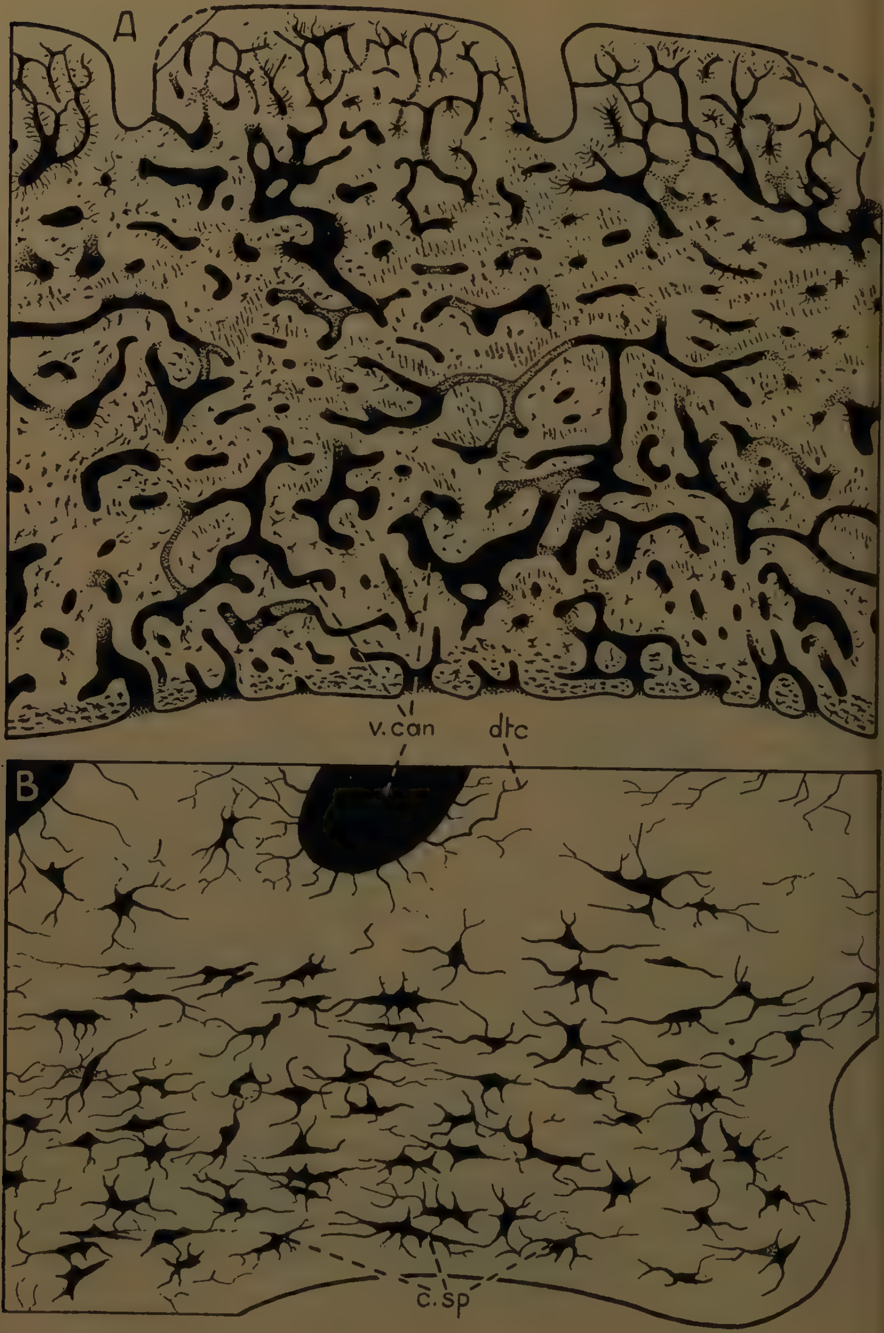


Fig. 12. *A*, *B*, *Byssacanthus dilatatus* (Eichw.). Upper Middle Devonian, Narova (*A*) and Salaca (Luga) beds (*B*), Esthonia. *A*, incomplete anterior median dorsal plate in ventral view and the dorsal spine belonging to this plate, from Gross 1940, fig. 10A; x 3. *B*, detached dorsal spine of a similar plate, from Gross 1940, fig. 10F; x 2. *C*, *D*, exoskeletal shoulder girdle of two Euarthrodires in lateral view; *C*, *Palaeacanthaspis vasta* Brotzen, Downtonian, Czortków Series, Podolia, from Stensiö 1944, fig. 3; x 5/2; *D*, *Rhamphodopsis trispinatus* Watson, Middle Old Red Sandstone, Scotland, from Watson 1938, fig. 1; approximately x 2.7. *E–G*, *Arthrodira* inc.sed., median dorsal plates, each showing an area of attachment for a dorsal spine. *E*, *F*, two plates of this kind from the Lower Devonian Wood Bay Series of Spitsbergen (Vestspitsbergen), Nos. B 186 (*E*) and B 180 (*F*) belonging to the Paleontological Museum, Oslo. Both specimens preserved as impressions in the rock and drawn from latex moulds in dorsal view (*E:1*, *F:1*) and in lateral view with the outline of the dorsal spine laid in (*E:2*, *F:2*); *E*, Mt. Høgkollen, Reinsdyrflya (Reindeer Peninsula); natural size; *F*, W side of Mt. Lykta, Dicksonfjorden; natural size. *G*, a small plate, very similar to that in *E*, Lower Old Red Sandstone, Herefordshire, England, Specimen No. D8 belonging to the Grindrod Collection in the University Museum, Oxford, figured by Lankester 1870, pl. 13, fig. 18; x 2.

Md, median dorsal plates; *f.sp.d*, fossa for the attachment of a dorsal spine; *sp*, pectoral spine; *sp.d.* dorsal spines.

allied forms), but in view of the fact that, in addition to the dentine of the ornamental ridges, they are made up of a special bony tissue with cell-spaces which is not met with in the exoskeleton of the Elasmobranchs in general, at any rate not in those I have had the opportunity to investigate histologically, there may be reason to suspect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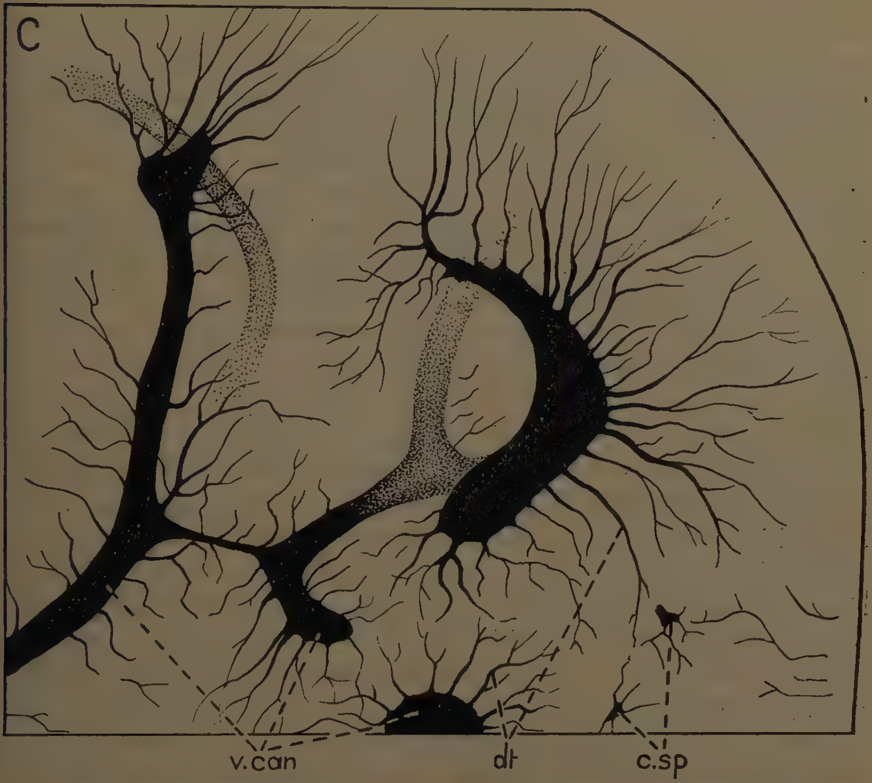

Fig. 13. *Gamphacanthus politus* (Newb.). Middle Devonian, Cedar Valley Limestone, Waterloo, Iowa. *A*, cross-section of the hard tissues in the proximal part of the spine, Section No. S 1325; x 30. *B*, *C*, more highly magnified details of the hard tissues: *B*, the basal bone tissue, Section No. 1324; x 300; *C*, the dentine of the ornamental ridges, same section as *A;* x 300.

c.sp, cell-spaces; *dt*, dentinal tubes; *dtc*, cell-canaliculi, resembling short dentinal tubes; *v.can*, vascular canals.

that they are not referable to this particular group of fishes at all. Another possibility which should be taken into consideration is that they belong to an Arthrodire. It lies near, for instance, to compare them with the powerful dorsal spines with a peculiar ornamentation on the exoskeletal shoulder girdle of such *Ptyctodontida* as *Rhamphodopsis* (*sp. d*, fig. 12 D), and it is not improbable that, as Eastman believed (1908, p. 139), they really represent detached spines of this kind. This is entirely conjectural, however, as long as it has not been proved that the *Ptyctodontida* includes forms whose exoskeleton exhibits cell-bearing bony tissue of the same special kind as in *Gamphacanthus*. Moreover, strong dorsal spines are also met with on the shoulder girdle of such forms as *Palaeacanthaspis* and *Byssacanthus* (fig. 12 A–C) and surely existed also in various other non-Ptyctodontid Arthrodires (cf. the median dorsal plates with an area of attachment for a dorsal spine in fig. 12 E–G, and the same plate in «*Coccosteus*» *angustus* from the lower Devonian of Germany as figured by Traquair 1903, pl. 6, fig. 1). If the *Gamphacanthus* spines really pertain to the Arthrodires, therefore, their affinities may not necessarily be with the *Ptyctodontida*.

In this discussion of Ichthyodorulites which may represent detached exoskeletal elements of Arthrodires, some words should also be said concerning the fragmentary dermal bones named *Oëstophorus lilleyi* (NEWB.) from the Hamilton beds of Milwaukee, Wisc., the Chemung of Pennsylvania, the Genesee group of New York etc. which show a very characteristic ornamentation of pointed, arrowhead-like tubercles, arranged in rows (Newberry 1889, pp. 91–92, pl. 20, fig. 15; Eastman 1908, p. 207, pl. 3, fig. 2; Hussakof & Bryant 1918, p. 105, pl. 33, fig. 1). To judge from the specimens I have been able to examine macroscopically, particularly a large, well preserved one belonging to the Museum of Paleontology of the University of Michigan, Ann Arbor, Mich., kindly placed at my disposal by Dr. C. W. Hibbard (No. 23495, Middle Devonian, Traverse group, presumably Norway Point formation, Alpena Co., Mich.), these bones very probably represent the broken-off antero-medial (apronic) lamina of anterior lateral plates in the shoulder girdle of some form belonging to the *Ptyctodontida* or to another Arthrodire group. This is clearly indicated by (a) the shape and other properties of the Ann Arbor specimen just referred to, and (b) the fact that in some of the *Rhynchodus* species from the Lower Upper Devonian *Manticoceras* beds of Wildungen in Germany as well as in *Williamsaspis bedfordi* WHITE from the Middle Devonian of New South Wales, this lamina bears an ornamentation which is indistinguishable from that of the *Oëstophorus* bones (see Jaekel 1929, fig. 89, Gross 1933 b, pl. 9, fig. 5; White 1952, pl. 28, fig. 1); cf. also in *Palaeacanthaspis vasta*, Stensiö 1944, *m. lam*, figs. 3, 7A, pl. 6, fig. 3, pl. 9, fig. 2).

5. Acanthodian jaw-bones (*Atopacanthus* sp.) from the Upper Middle Devonian *Asterolepis scabra* beds of Fiskekløfta in Mimerdalen, Spitsbergen.

In the very comprehensive material of fossil vertebrates brought home from the Red Bay and Wood Bay Series of Northwestern Spitsbergen (Vestspitsbergen) by the earlier Norwegian and Swedish expeditions and the English-Norwegian-Swedish (ENS) expedition of 1939, there are numerous Acanthodian remains which have only been briefly referred to in the literature (e. g. by Kiær 1916, p. 493, and Stensiö 1918, p. 68). The collections include (a) *Nostolepis* and «*Gomphodus*» scales which occur in association with Thelodontid scales and other vertebrate microfossils in various parts of the Red Bay and Wood Bay Series (see p.288); (b) large tooth-whorls of the *Protodus* kind and other tooth-bearing jaw-bones (*Plectrodus*) from the upper part (horizon J, etc.) of the Ben Nevis Division of the Red Bay Series; (c) *Climatius* and «*Onchus*» spines from the Frænkelryggen Division (*primaeva* horizon, etc.) of the Red Bay Series, and (d) two large spines, to some extent suggestive of «*Onchus*» *overathiensis* GROSS (Gross 1937, fig. 29, pl. 8, fig. 8) from the upper part of the Kapp Kjeldsen Division of the Wood Bay Series (ENS-specimens; Field-No. 111, Barmfjellet, NW of the inner end of Dicksonfjorden, and Field-No. 25, N slope of Roosfjella on the peninsula between Liefdefjorden and Bockfjorden).

In addition to their rich vertebrate fauna consisting of *Heterostraci* (*Psammosteus* or *Psammolepis*), *Arthrodira* (*Holonema*) *Antiarchi* (*Asterolepis*) *Crossopterygii* (*Dictyonosteus*, «*Onychodus*», *Glyptolepis*, possibly also *Rhizodontida*) and *Actinopterygii* (*Rhadinichthys*) the Upper Middle Devonian shales and sandstones of the Fiskekløfta (Fish Ravine) area in Mimerdalen, W of Billefjorden (the *Asterolepis scabra* Series according to Nilsson 1941) have also yielded scales, spines and jaw-bones of Acanthodians. The scales and spines cannot at present be determined satisfactorily as to genus or species. The tooth-bearing jaw-bones on the other hand which have earlier been interpreted as «Fragmente von Coccosteiden-Kiefern» (Stensiö 1918 p. 69; see also Stensiö 1925 pp. 176–177; Heintz 1932 p. 146; 1935 pp. 116 120; Nilsson 1941 p. 46; Vogt 1941 p. 4) are clearly referable to the genus *Atopacanthus* HUSSAKOF & BRYANT of which two species have been described previously from the Middle and Upper Devonian of North America viz. *A. peculiaris* (HUSSAKOF) from the Onondaga formation of Delaware Co., N. Y. and *A. dentatus* HUSSAKOF & BRYANT from the Rhinestreet Shale near Buffalo, N. Y. (Hussakof 1913 pp. 247–248 fig. 2 pl. 47 figs. 4–6; Hussakof & Bryant 1918 pp. 157–158 fig. 54). A short description is given in the sequel of those jaw-bones which have not been figured before. From the point of view of taxonomy they are probably not identical with either *A. dentatus* or *A. peculiaris* but for want of definite distinctive characters they have not been given any specific name of their own here.

In Spitsbergen, Acanthodian jaw-bones of the genus *Atopacanthus* also occur in association with such forms as *Lunaspis*, *Dolichothoraci* gen. et. sp. indet., *Onychodus* etc. in a dark shale from the S side of Skamdalen (Short Valley), W of Wijdefjorden (Ørvig 1957 a p. 393) which, since it belongs to the Grey Hoek Series is considerably older than the *Asterolepis scabra* beds of Fiskekløfta (it may, in point of fact, be broadly contemporary to, or at any rate not much older than, the Onondaga beds of North America yielding *A. peculiaris*, *Onychodus* etc.). The *Atopacanthus* sp. from this particular locality will be dealt with in another connection.

CLASS ELASMOBRANCHIOMORPHA.

SUBCLASS ACANTHODII.

ORDER ISCHNACANTHOMORPHI.

FAMILY ISCHNACANTHIDAE WOODWARD.

In addition to the type genus *Ischnacanthus* POWRIE of which numerous articulated specimens have been collected from the Dittonian (Turin Hill beds) of Angus, Scotland, this family surely also includes various other forms which are represented by detached exoskeletal elements in bone bed material of Upper Silurian, Downtonian, Dittonian and Middle Devonian age. The latter cannot, of course, be defined, but to judge from the condition of *Ischnacanthus* (various specimens of *I. gracilis*, particularly No. 1887. 35.2 belonging to the Royal Scottish Museum, Edinburgh, figured by Watson 1937, pl. 9 fig. 2), everything goes to prove that they possessed *Plectrodus* jaw-bones on the palatoquadrate and Meckel's cartilage, a *Protodus* tooth-whorl in the symphysis of the lower jaw and several similar tooth-whorls and other tooth-bearing plates in the mouth cavity, «*Onchus*» fin-spines, «*Gomphodus*» body-scales and *Poracanthodes* lateral line-scales (see Gross 1947, p. 155). All those exoskeletal parts are distinguishable from those of *Climatius* and other members of the *Climatiomorphi* (*Nostolepis* etc.) with which they are frequently associated in the rock, by the microstructure of their hard tissues (particularly the dentine) and as a rule also by such external characters as ornamentation etc.

GENUS *Atopacanthus* HUSSAKOF & BRYANT.

1913. *Apateacanthus* (errore) —, L. Hussakof, p. 247.
1918. *Atopacanthus* n. gen. —, L. Hussakof & W. L. Bryant, pp. 157–158.
1923. *Atopacanthus* HUSSAKOF & BRYANT —, D. S. Jordan, p. 97.
1929. *Atopacanthus* HUSSAKOF & BRYANT —, O. P. Hay, p. 618.
1950. *Atopacanthus* —, W. Gross, pp. 79, 86, 90.
1957. *Atopacanthus* —, T. Ørvig 1957a, p. 393.

Diagnosis. A medium-sized genus of *Ischnacanthidae*. Jaw-bones of palatoquadrate and Meckel's cartilage slender, with fine, longitudinal striation on their lateral and medial faces, diminishing in height anteriorly, bearing a lateral row of teeth which decrease in size backwards, and frequently also a medial row of smaller teeth. Teeth completely anchylozed to jaw-bones, as a rule without side-cusps, consisting of dentine, containing a large undivided pulp cavity in their basal part. Jaw-bones made up of acellular bone tissue, cancellated in their interior. (Spines, scales, shape of body, number and position of paired and unpaired fins unknown).

Material. In addition to numerous fragments, the following more or less complete specimens were available to me for study: Nos. A. 21546–21548, A 21799 and A 22834 belonging to the Paleontological Museum, Oslo, collected by Vogt's expedition of 1928; Nos. P 474, P 491 a–c, P 494 and P 503 belonging to the Palaeontological Institute of the Uppsala University, collected by Stensiö in 1916; and Nos.

P 5058–5062 belonging to the Dept. of Paleozoology of the Swedish Museum of Natural History in Stockholm, collected by Nathorst in 1882 and Högbom in 1910. One of the specimens (Uppsala No. P 503) is preserved as an impression in a greyish sandstone; the others are all contained in ironstone nodules.

Geological horizon and locality. Upper Middle Devonian, *Asterolepis scabra* beds, the Fiskekløfta area of Mimerdalen, Spitsbergen. The age of the deposits is well established (Heintz 1937; Nilsson 1941; Føyn & Heintz 1943; etc.) and needs no further comment here. According to some writers (Føyn & Heintz op. cit., p. 48; and others) the lower part of the Devonian of Fiskekløfta and vicinity corresponds to the upper part of the Wijde Bay Series further to the north. Nilsson, on the other hand, has expressed the opinion (cp. cit., pp. 47–48) that the Fiskekløfta beds are younger than the Wijde Bay Series and that, in fact, they represent a series of their own, the Series with *Asterolepis scabra*. This name has not been taken up, however, in the recent issue of the «Lexique Stratigraphique International» dealing with Spitsbergen (Vol. 1, Fasc. 1d, Paris 1956) where the Fiskekløfta layers are referred to the Wijde Bay Series.

Description. The individual jaw-bones consist of a slender element to the superficial part of which teeth of varying size and distribution are anchylozed. The length of these bones is mostly 27–32 mm (pl. 2, figs. 1, 2, 5; Uppsala No. P 503), but in a particularly large specimen, of which only a fragment is preserved (Uppsala No. P 473), it may be estimated at 60 mm, or thereabouts. The bony element supporting the teeth is low and narrow in its most anterior part, gradually increasing in height and breadth in a posterior direction (pl. 2, figs. 1, 4, 5). Its lateral and medial faces exhibit a fine, longitudinal striation. On its medial side it shows a basally protruding lamina which extends from its anterior almost to its posterior end (figs. 14, 15 A, B). Its basal face, which is bounded off by this lamina medially, is flat or, sometimes, a little concave (figs. 14, 15 A, B).

With regard to the arrangement of the teeth, one may distinguish two types of jaw-bones, here referred to as type A and B, respectively.

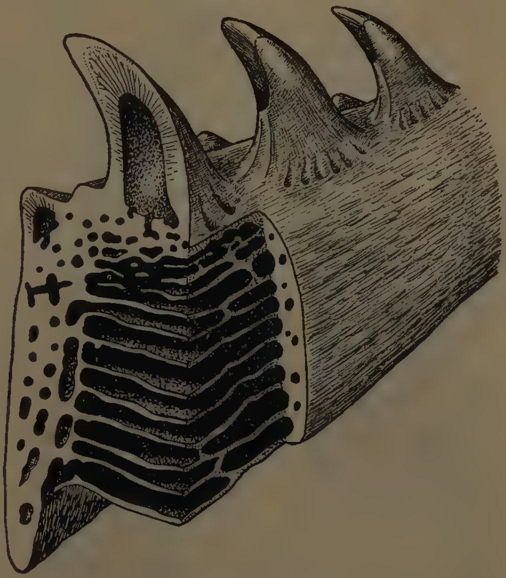

Fig. 14. *Atopacanthus* sp. Diagram illustrating the structure of a jaw-bone with a lateral and a medial row of teeth. Antero-dorso-lateral view. Approximately x 15.

In type A there are two longitudinal rows of teeth, lateral and medial (*dl*, *dm*, figs. 14, 15 C, pl. 2, fig. 2). The former, which consists of 12 teeth, or more, extends backwards from the anterior end of the jaw-bones for about two thirds of their entire length, or in some cases almost to their posterior end (*dl*, pl. 2, figs. 1, 2). The teeth in this row, which are without side-cusps, are all bent medially (figs. 14, 15 B, pl. 2, figs. 1, 2). Anteriorly they are fairly large but posteriorly they gradually decrease in size. They are somewhat depressed in a latero-medial direction, tapering to a sharp point apicially and smooth except in their basal part where they are ornamented with a system of shallow, radiating grooves (fig. 14, pl. 2, figs. 1, 2). Between each tooth in the lateral row and the succeeding one, the superficial face of the jaw-bones exhibits a fairly deep concavity. Medially the lateral row of teeth is bounded off by a horizontal, well-defined margin, and just underneath this margin, on the most superficial part of the medial face of the jaw-bones, the medial row of teeth is met with (*dm*, figs. 14, 15 C, pl. 2, figs. 2). In this row, which is much shorter than the lateral one in that is confined to the posterior half, or so, of the jaw-bones, the teeth are small and fairly blunt (fig. 14, *dm*, pl. 2, fig. 2).

In type B (fig. 15 A, pl. 2, figs. 3–5) there is only a lateral row of teeth which are similar to those of the corresponding row in type A except in that (a) they are all bent posteriorly and a little medially (pl. 2, figs. 4, 5); and (b) some of them may exhibit a small side-cusp

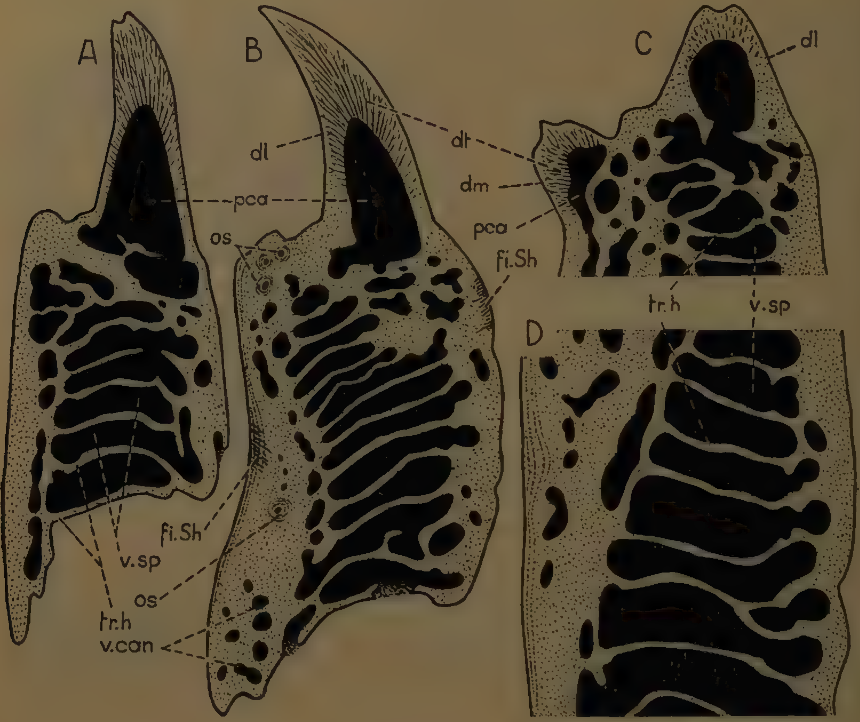

Fig. 15. *Atopacanthus* sp. Upper Middle Devonian, *Asterolepis scabra* beds, Fiskekløfta, Mimerdalen, Spitsbergen (Vestspitsbergen). Sections of jaw-bones, cut orthogonally to their axes of length; approximately x 23. *A*, from a grinding series of a jaw-bone with a lateral row of teeth only; the tooth in this section is cut a little anteriorly to its apical part. *B–D*, from another grinding series of a jaw-bone with a lateral and a medial row of teeth, showing *B*, a lateral tooth, *C*, a medial tooth and the most posterior part of a lateral tooth, and *D*, the system of bony lamellae in the interior of the jaw-bone.

dl,dm, lateral and medial teeth, respectively; *dt*, dentinal tubes; *fi.Sh*, canals for fibres of Sharpey penetrating into the jaw-bones from their lateral and medial sides; *pca*, pulp cavities of the teeth; *os*, osteons; *tr.h*, bony lamellae in the interior of the jaw-bones; *v.can*, vascular canals; *v.sp*, spaces, presumably vascular, in the interior of the jaw-bones.

in their posterior part (pl. 2, fig. 4). In superficial view the jaw-bones of type B show the same concavities between, and horizontal margin medially to, the lateral row of teeth as in type A (pl. 2, fig. 3).

All teeth of the jaw-bones consist of typical dentine (orthodentine), penetrated by fairly straight, somewhat branching dentinal tubes which radiate in a superficial direction from a large basal pulp cavity (fig. 14, *dt*, *pca*, fig. 15 A–C, *dt*, pl. 5). In ordinary light the external layer of the dentine, which contains the terminal ramifications of the dentinal tubes (*eel*, pl. 5, fig. 1), is to some extent reminiscent of the enamel-like substance of the teeth in various other Elasmobranchiomorph fishes. Between X nicols, however, it shows none of the optical properties of this particular substance (a circumstance which cannot be due to the state of preservation alone since, in the same sections as the *Atopacanthus* jaw-bones, there are also various Crossopterygian teeth in which the external enamel layer is always sharply distinguishable from the dentine by its high birefringence).

Apart from the teeth, the jaw-bones throughout their extent consist of a bone tissue which is entirely devoid of cell-spaces (fig. 15, pl. 5, fig. 1). On their lateral and medial sides the bone tissue is fairly dense, containing some vascular canals which are mostly surrounded by primary osteons (*v. can*, *os*, fig. 15 B, pl. 5, fig. 1). In their interior on the other hand, this hard tissue is cancellated, consisting of a system of thin lamellae which form horizontal or slightly oblique partition floors between a series of longitudinal, fairly wide spaces, presumably vascular spaces (fig. 14, *tr. h*, *v. sp.* fig. 15, pl. 5, fig. 1).

There is every reason to believe that the *Atopacanthus* jaw-bones originally occupied the same positions in relation to the visceral endoskeleton as in *Ischnacanthus gracilis* (Dean 1907; Goodrich 1909, pp. 189–190; Watson 1937, pp. 79–80, pl. 9, fig. 3 a). More precisely, in *Atopacanthus* the palatoquadrate of each side carried one of those jaw-bones which in biting worked against another on the opposing Meckel's cartilage. It may well be that the two types of jaw-bones referred to above represent the dentition of the upper and lower jaws in the same individuals, but it is also possible, of course, that they belong to different species. The manner of attachment of the jaw-bones to the supporting cartilaginous elements cannot be finally decided on the basis of the material at my disposal. It is most conceivable, perhaps, that the basal face of the individual jaw-bones rested directly against the perichondrium of the cartilage, and that the spaces in the interior of those bones contained vessels and connective tissue. The possibility also exists, however, that the cartilage extended further in a superficial direction into the jaw-bones and that, consequently, the cancellous hard tissue in the interior of those bones (fig. 14, *tr. h*, fig. 15, pl. 5, fig. 1) formed enchondrally. For a further discussion of this question the reader is referred to the forthcoming 2nd part of my «Histologic studies of Placoderms and fossil Elasmobranchs».

As far as I can judge from a macroscopical examination of the specimens, the *Atopacanthus* jaw-bones from North America are very suggestive of those from the *Asterolepis scabra* beds of Fiskekløfta where their general shape and microstructure are concerned (*A. dentatus:* BMS No. E 2496; *A. peculiaris:* AMNH Nos. 413, 873, — Newberry Collection, NYSM No. 10330; see Hussakof 1913, pl. 47, figs. 4–6; Hussakof & Bryant 1918, fig. 54). The only (and presumably rather insignificant) difference that I can find between them is that specimens showing a medial row of teeth in addition to the lateral one seem to be absent in the American material. The *Atopacanthus* jaw-bones from Spitsbergen and North America are similar in many ways to those of *Ischnacanthus* (Dean 1907; Goodrich 1909, fig. 160; Watson 1937, pl. 9, fig. 3 a) and the other representatives of the *Ischnacanthomorphi* from the Upper Silurian and Lower Devonian (Murchison 1867, pl. 35, figs. 3, 4, 6, 7; Priem 1910, pl. 1, figs. 7–10; Stensiö 1932 pl. 53 fig. 6; Gross 1947 pl. 28 figs. 10–14; 1957; and others; the writer's observations on various material). On the other hand, they are distinguishable from the latter by the following characters: (a) the absence of a series of small denticles between the teeth of the lateral row; (b) the presence of a large, undivided pulp cavity in the teeth instead of a system of ascending and anastomozing vascular canals; and (c) the highly cancellated structure of the bone tissue in the interior of the jaw-bones.

It may be pointed out here, finally, that the account of the teeth and jaw-bones of the *Brachythoraci* given by Stensiö in 1925 (pp. 176–177) is based to a large extent on the condition of *Atopacanthus* from Fiskekløfta. As I will show in the 2nd part of my «Histologic studies» just referred to, however, the dentition of this group of Arthrodires is in several respects different from that of *Atopacanthus* and the *Ischnacanthomorphi* in general.

6. The calcified cartilage of two Paleozoic Elasmobranchs from North America, *Tamiobatis vetustus* EASTM. and *Coelosteus ferox* NEWB.

Based on Eastman's description of *Tamiobatis vetustus* from the Devonian of Kentucky (Eastman 1897 a, pl. 1, fig. 1), I have earlier suggested (Ørvig 1951, foot-note *1* on p. 416) that the endocranium in this form is reminiscent of that in several Coccosteomorph Brachythoracids and other Arthrodires as well where its hard tissues are concerned or, more precisely, that it is «lined with perichondral bone and that a subperichondral calcified layer is exposed in those places where the bone layer has been weathered away» (Ørvig, loc. cit.). Consequently I assumed that *Tamiobatis* in all probability is referable to the Arthrodires. When I saw the actual fossil (USNM-specimen), however, I soon found that Eastman's description of the endoskeletal hard tissue is inaccurate. The whole endocranium is encrusted superficially by perfectly genuine prismatic calcification, such as never seems to occur in any of the Arthrodires. It is rather obvious, therefore, that *Tamiobatis* is a true representative of the *Elasmobranchii.*

In 1889 Newberry (pp. 188–191, pl. 35, figs. 1–3) described a jaw-element of a large fish from the Lower Carboniferous (Mississippian) St. Louis Limestone of Alton, Ill. to which he gave the name of *Coelosteus ferox*. Newberry referred this fossil with some hesitation to the Crossopterygians, and in this group it has repeatedly been placed since (e. g. by Hay 1929, p. 677; and Gross 1933 a, p. 62), allthough Woodward long ago (1891, p. 346) identified it as «the superficially calcified meckelian cartilage of an Elasmobranch». Both the macroscopical aspect of the holotype of *C. ferox* (AMNH No. 106 G, — Newberry Collection), and the two sections I most generously got permission to make of it in New York, fully confirm Woodwards opinion just referred to. The specimen is a Meckel's cartilage with a row of shallow, pit-like depressions for the attachment of teeth on its dorsal part. Throughout its extent it is lined superficially with a thin crust of lime-prisms (*pcc*, fig. 16), perfectly similar to the «Rindenverkalkung» of Elasmobranchs in general (see Ørvig 1951, and the

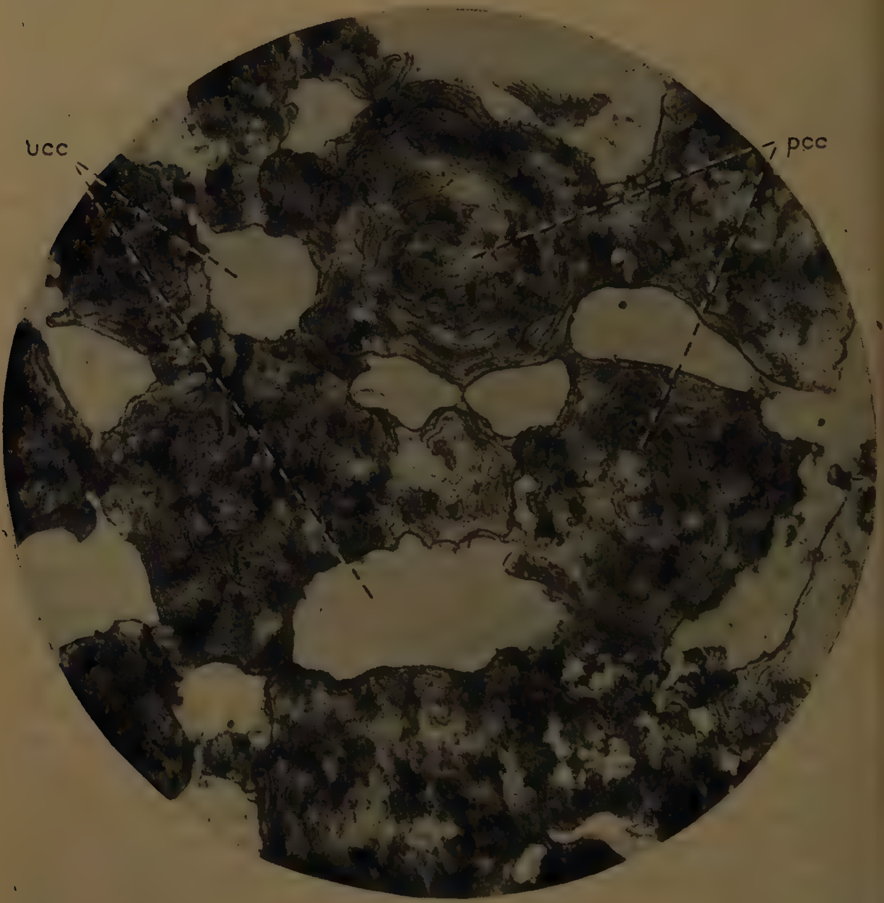

Fig. 16. *Coelosteus ferox* New. Lower Carboniferous (Mississippian), St. Louis Limestone, Alton, Ill. Calcified cartilage. Section No. S 1281; x 100.
pcc, prismatic calcified cartilage; *ucc*, matrix-filled spaces between the prisms, originally containing isles of uncalcified cartilage.

literature cited in that work). Underneath the superficial crust it is entirely devoid of calcifications. The prisms (*pcc*, fig. 16) show the usual structure in ordinary and polarized light, and between them there are nodules or irregular trabeculae of globular calcified cartilage. A corresponding layer of lime-prisms is clearly perceptible also on the surface of certain rod-like elements from the St. Louis Limestone of Illinois (USNM-specimens) which very probably represent parts of gill arches or other components of the visceral endoskeleton of *Coelosteus ferox* or a related form.

According to St. John & Worthen (1883) and Newberry (1889) the St. Louis Limestone of Alton, Ill. and other localities in the same area has yielded a great many detached teeth, tooth plates and spines of Elasmobrachs, representing a variety of different forms. Since, in the older literature, the St. Louis Limestone has frequently been taken in a rather wide sense (see Weller et al. 1948, p. 124), one cannot be absolutely certain that all those exoskeletal elements are derived from the same beds as the Meckel's cartilage of *Coelosteus ferox*, but it may well be nevertheless, that some of them belong to the same kind of fish as the latter. As far as one can judge, this Meckel's cartilage is rather unlike that of the *Cochliodontida*, and everything goes to indicate, therefore, that it had nothing to do with the isolated teeth and tooth plates of this group of the *Bradyodonti* in the fauna (*Psephodus, Cochliodus, Sandalodus, Deltoptychius, «Chitonodus», Poecilodus, «Deltodopsis»*), nor with such curved or hooked spines (*Physonemus, Harpacanthus*) which presumably occupied a position at the posterior end of the lower jaw or on the dorsal side of the head in forms more or less closely related to *Oracanthus* or *Menaspis*. For various reason it is also inconceivable, I think, that it can have had any connection whatsoever with the tooth plates of such representatives of the *Bradyodonti* as *Psammodus* or *Copodus*. On the other hand, this Meckel's cartilage is in several ways suggestive of that in the *Pleuropterygii*, and it is not impossible that its affinities are with some of the *Ctenacanthida* whose spines are frequently met with in the St. Louis Limestone.

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PLATES 1–5

PLATE 1.

Ellopetalichthys scheii (KIÆR).

Upper (?) Middle Devonian, Series D, Goose Fiord, Ellesmere Land. Holotype, Specimen No. A 13047 belonging to the Paleontological Museum, Oslo. Figs. 1, 5, 6 taken in xylene.

Figs. *1*, *2*, incompletely preserved dermal skull-roof. *1*, in dorsal, and *2*, in posterior view; x 2.

Figs. *3*, *4*, the perichondral ossifications in the occipital region of the endocranium. *3*, in ventral, and *4*, in postero-ventro-lateral view; x 2.

Figs. *5*, *6*, details of the pores by which the lateral line canals open on the external surface of the dermal skull-roof. *5*, the supraorbital canal, and *6*, the cephalic division of the main lateral line canal; approximately x 10.

Oc.a, *Oc.p*, anterior and posterior occipital; *cr.ol*, crista occipitalis lateralis; c_x, opening for the n. vagus; *f.gl*, glenoid fossa; *gr.hae*, haemal groove; *ifc*, infraorbital lateral line canal; *lc*, cephalic division of the main lateral line canal; *n.da?*, notch for the radix aorta; *orb*, orbital openings; plx_{scu}, impressions of canals of a subcutaneous vascular plexus situated close underneath the basal layer of the dermal bones of the skull-roof; *po*, external pores of the lateral line canals; *pp*, posterior pit-line canals; $pr.po_p$, posterior postorbital process; *pr.v*, ventral process of the posterior paranuchal plate; *ri.nch*, notochordal ridge; *ri.tv*, transverse ridge of the posterior occipital; *soc*. supraorbital lateral line canals; *t*, tubercles; *tu*, tubes of the lateral line canals.

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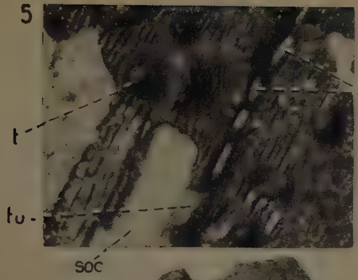
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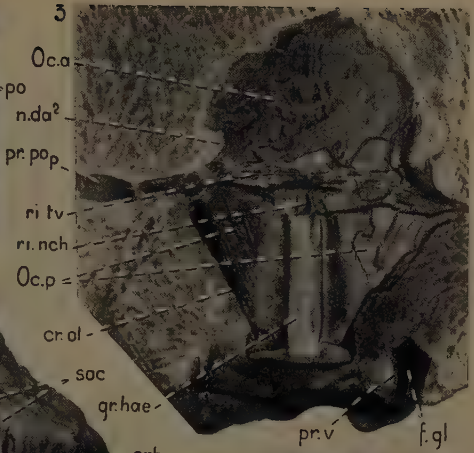
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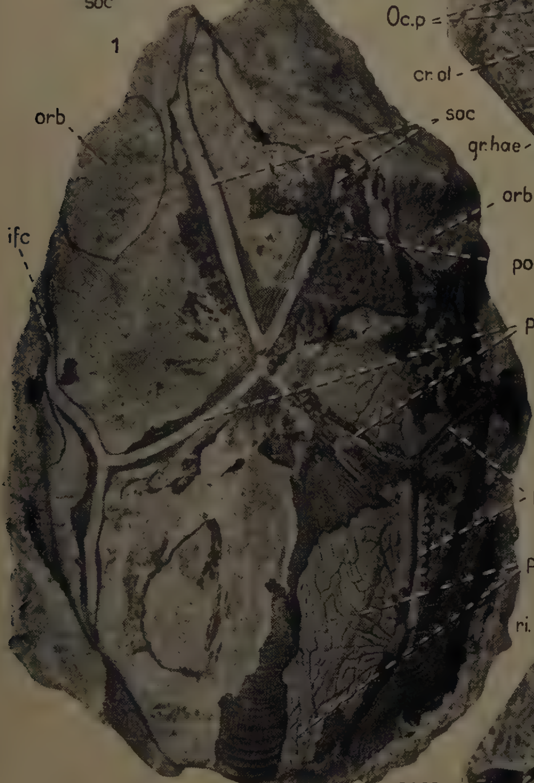
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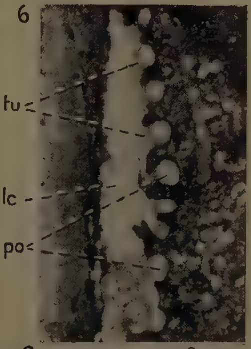
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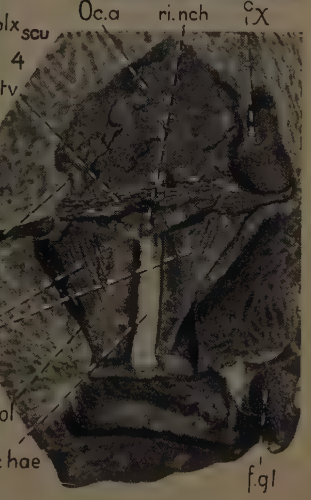
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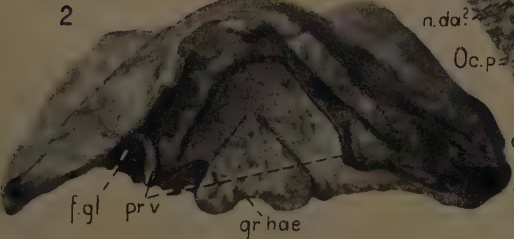
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PLATE 2.

Atopacanthus sp.

Jaw-bones; Upper Middle Devonian, *Asterolepis scabra* beds, Fiskekløfta, Mimerdalen, Spitsbergen (Vestspitsbergen). All figures x 4; fig. *2* taken in xylene. Specimens belonging to the Paleontological Museum, Oslo (*1*: No. A 21548), the Palaeontological Institute of the Uppsala University (*2:* No. P 493; *3:* No. P 491c; *5:* P 474) and the Dept. of Paleozoology of the Swedish Museum of Natural History in Stockholm (*4:* No. P 5060).

Figs. *1*, *2*, jaw-bones with a lateral and a medial row of teeth. *1*, a specimen in dorso-lateral view (the medial row of teeth not freed from the matrix). *2*, another specimen in medial view, showing both rows of teeth.

Figs. *3–5*, jaw-bones with a lateral row of teeth only. *3*, a specimen in dorso-medial view. *4*, *5*, two other specimens in lateral view.

dl, *dm*, lateral and medial rows of teeth, respectively; *ri.m*, ridge medially to the lateral row of teeth.

PLATE 2

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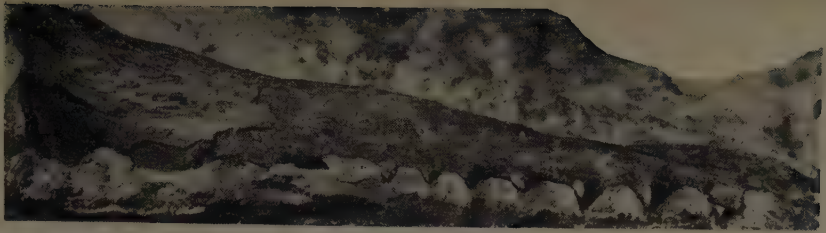

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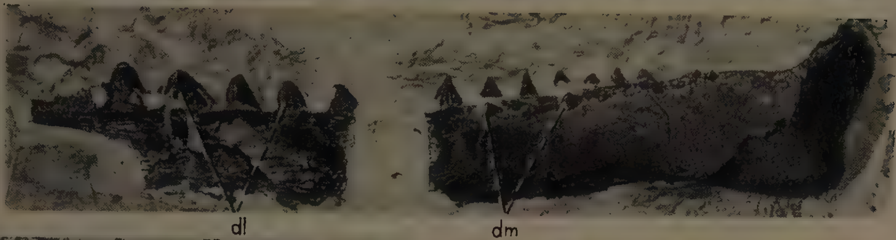

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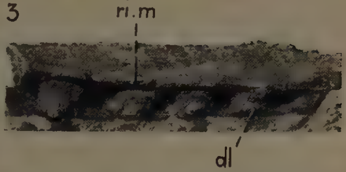

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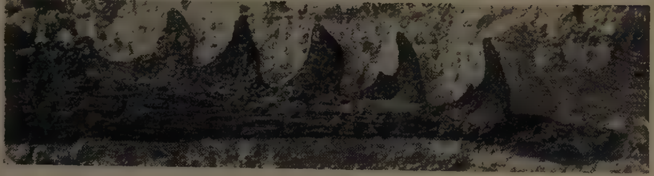

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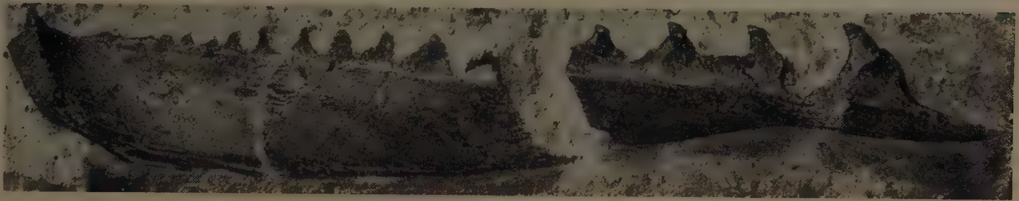

PLATE 3.

Dunkleosteus cf. *terrelli* (Newb.).

Upper Devonian, Ohio Shales formation. Section of the perichondral bone of a fin radial; section No. S 1257; approximately x 60.

b.pch.b, basal face of the perichondral bone; *can.e*, ascending vascular canals in the superficial part of the perichondral bone; *can.i*$_c$, *can.i*$_l$, vascular canals in the basal part of the perichondral bone, directed concentrically around the long axis of the fin radial, and parallelly with that axis, respectively; *lam*, lamination of the perichondral bone, and *lam'*, inwardly bending lamination at the margins of the ascending vascular canals in the superficial part of the bone; *s.pch.b*, superficial face of the perichondral bone.

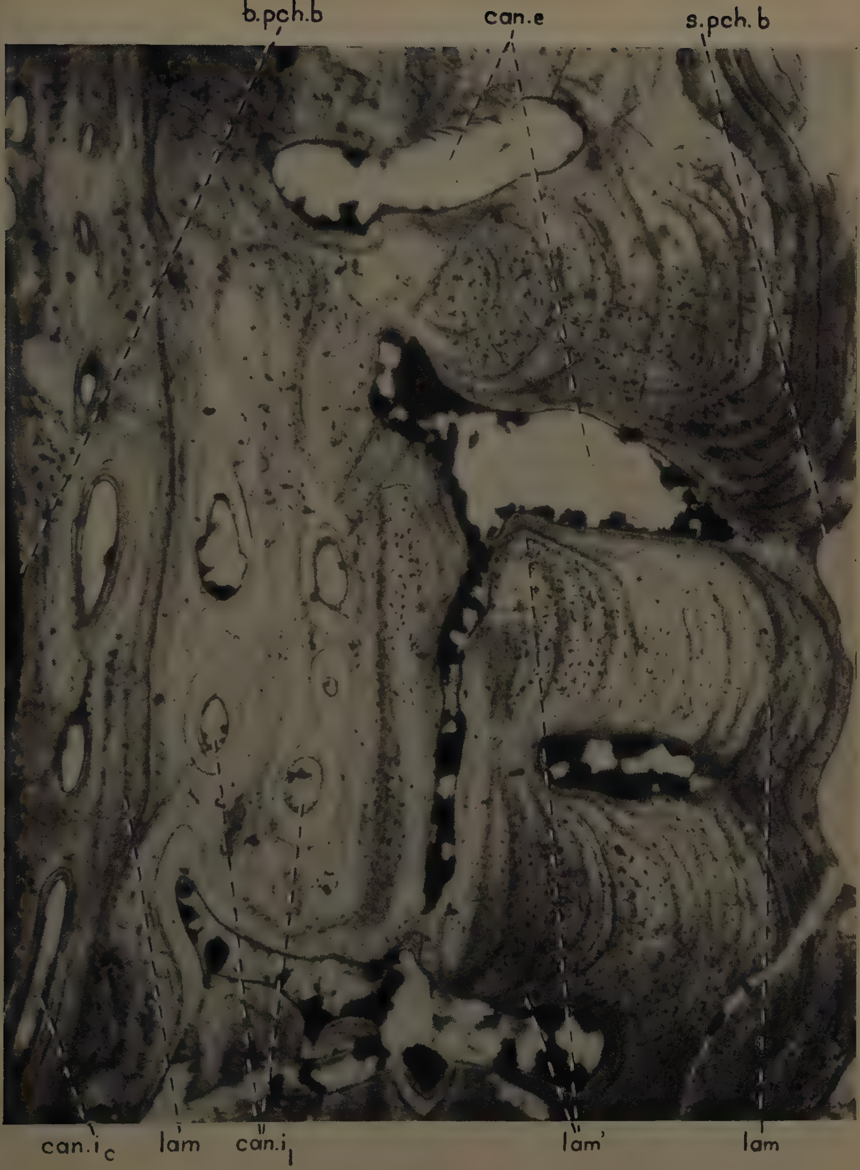
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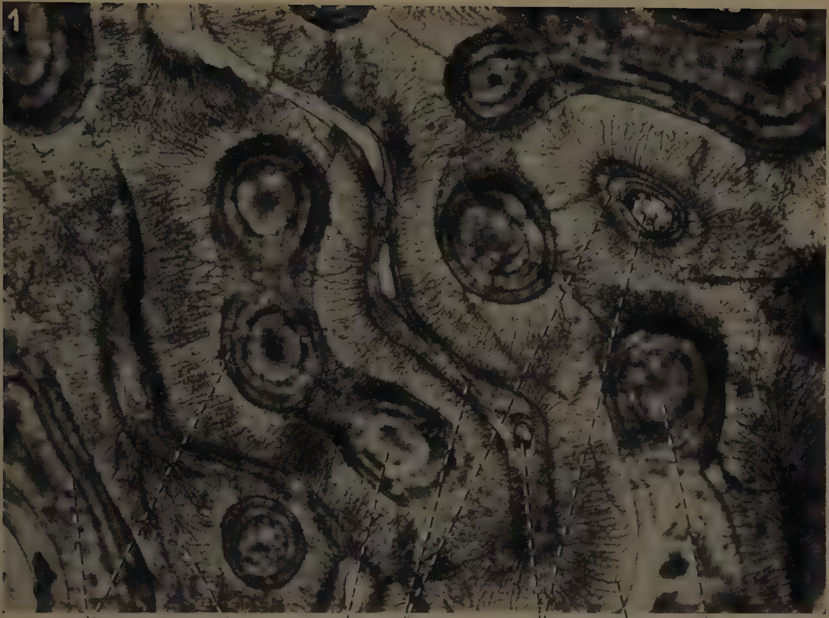
PLATE 4.

Palaeomylus greenei (NEWB.).

Tooth plate; Devonian of the U.S.A.; locality and stratigraphical level unknown. Section of the osteodentine-like hard tissue in the symphysial tritorial column, cut about perpendicularly to the long (vertical) axis of that column. Section No. S 1268; x 100. Fig. *1*, in ordinary light; fig. *2*, between X nicols.

dt, dentinal tubes; $e.os_d$, $i.os_d$, outer and inner portions of the systems of circumvascular dentine, respectively; *iost*, interstitial zones of bony tissue separating the systems of circumvascular dentine from each other, and *lam*, concentric lamellation of this bony tissue; *v.can*, vascular canals.

PLATE 4



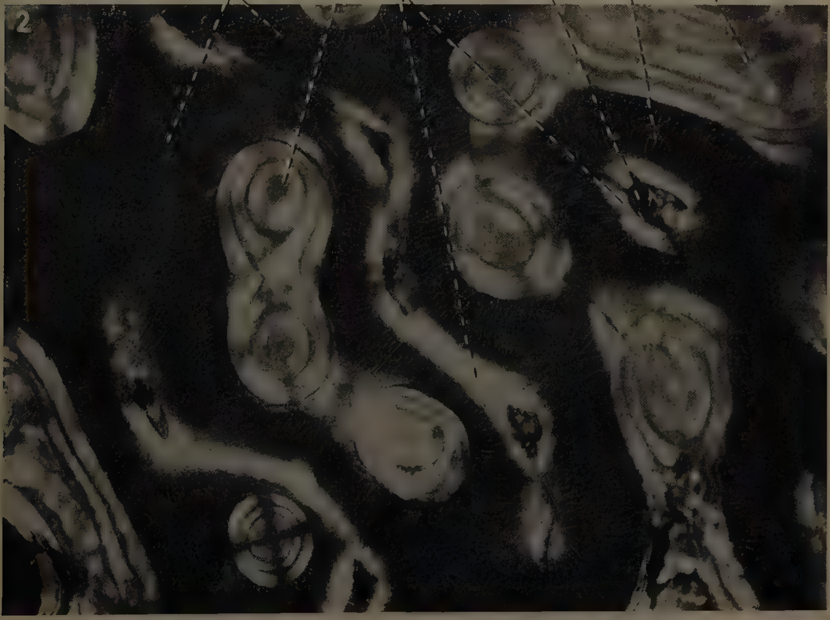


PLATE 5.

Atopacanthus sp.

Upper Middle Devonian, *Asterolepis scabra* beds, Mimerdalen, Spitsbergen (Vestspitsbergen).

Fig. *1*, section of a medial tooth and the cancellated bone tissue in the interior of a jaw-bone. The tooth is cut so obliquely that its basal pulp cavity is not shown. Section No. S 143; x 125.

Fig. *2*, oblique section of the apical part of a tooth,. Section No. S 141, approximately x 200.

dm, medial tooth; *dt*, dentinal tubes; *eel*, superficial part of the dentine; *os*, osteons; *tr.h*, bony lamellae in the interior of the jaw-bone, and *v.sp*, spaces, presumably vascular spaces, separated from each other by those lamellae.

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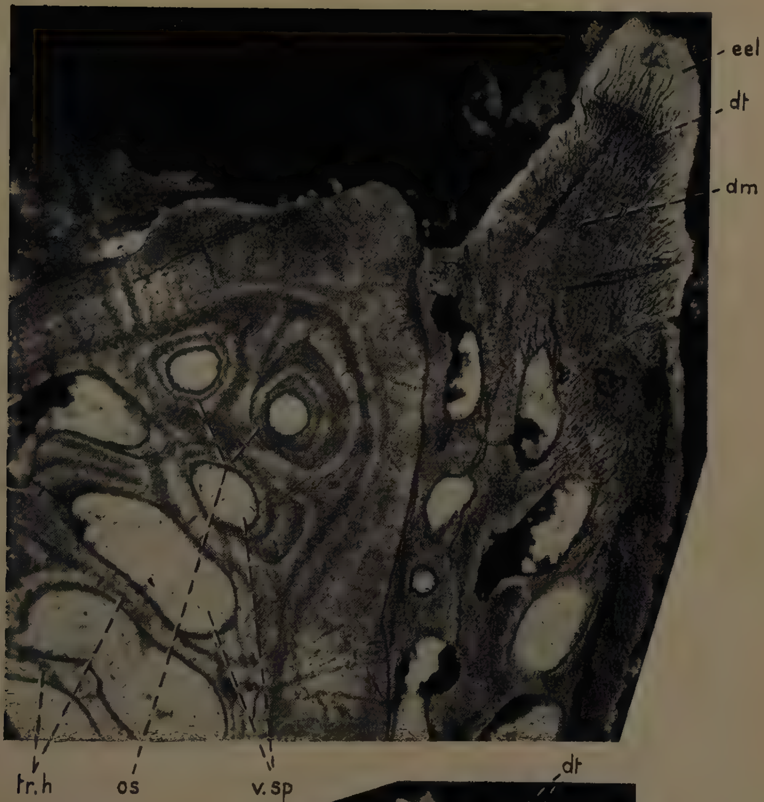

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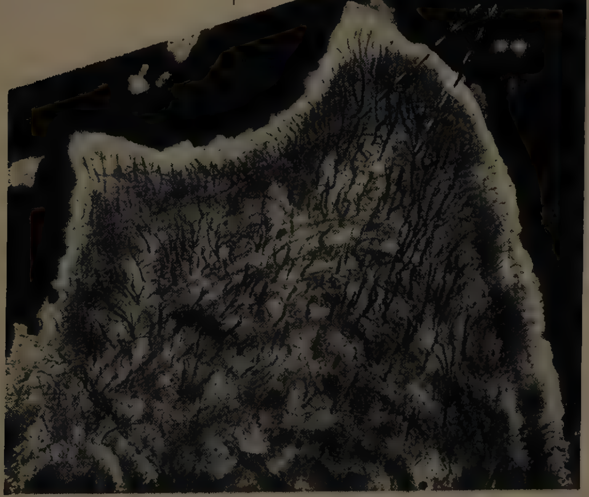

THE SILURIAN/ORDOVICIAN BORDER IN THE OSLO DISTRICT

BY

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Abstract. It is suggested that the Ordovician/Silurian boundary should be placed at the base of the beds with *Climacograptus scalaris normalis* and that Southern Wales should be regarded as the type area. An angular unconformity is described from the Oslo District, just below the Ordovician/Silurian border. The stratigraphy of the uppermost Ordovician and the basal Silurian is described and it is concluded that the orogeny started in 5a, reached a maximum in 5b, and faded out in 6 (Upper Llandovery).

Introduction

This paper is a preliminary report on the author's work, and it is presented here because the final results will not be completed for several years. The results were presented at the Second Nordic Geologic Winter Meeting in Oslo 1956 (SPJELDNÆS 1956).

The names of localities mentioned in the text, and the general geological structure are clearly shown on the map in HOLTEDAHL & DONS (1957).

In the Oslo District, the transition between the Ordovician and the Silurian has been described especially by KIÆR (1908), but details are given also by BRØGGER (1887). KIÆR's paper (1902) on the development of the uppermost Ordovician in the Asker District (to the West) is also important in this connection.

I am deeply indebted to Prof. O. Holtedahl, Prof. L. Størmer, Dr. G. Henningsmoen and Geologist H. Major for valuable discussions in connection with this paper.

The Ordovician-Silurian Border

The Ordovician-Silurian border has been placed at different levels by Scandinavian stratigraphers. KIÆR, in his first papers (1897, 1902) tried to escape the problem by making a new system, «Mittelsilur» between the Ordovician («Untersilur») and the Silurian («Obersilur). Later (1908) he placed the border between stages 5b and 6a. Later on again he placed the border below 5b, and above 5a. Most other Scandinavian stratigraphers have also used this border (5a/5b). This border is based on the supposed large break between the Dalmanitina-beds and the Tretaspis beds. This break is undoubtly present in Sweden, but in Norway, the break between stage 5b (corresponding to the Dalmanitina-beds in Sweden) and 6a is much more important. It must also be stressed that the border can not be placed at the position which is most convenient in each area. In order to be useful it must be isochronous in all areas. (Cf. SPJELDNÆS 1956). It is therefore necessary to select a type area, and correlate all the others with this area, even if the resulting border will be an inconvenient one in most areas. It is natural to use South Wales as the type are, because the oldest descriptions of Silurian are from that area. This has also been indicated by JONES (1949), and is also accepted long time ago by all British stratigraphers. Most Scandinavian stratigraphers also use this principle now.

The long-distance correlations are mainly done with the aid of graptolites in the Silurian, and WÆRN (1948) and DAVIES (1929) have showed a perfect agreement in the development of the graptolites in Great Britain and Scandinavia in the lowest Silurian. The find of a specimen of the lowest variety of *Climacograptus scalaris normalis* from the lowest part of zone 6aα at Ormøya in the Oslo District, therefore indicates that the border between the Ordovician and the Silurian in the Oslo District should be drawn between stages 5b and 6a. The same low variety indicate the very base of the Silurian in Britain (cf. DAVIES 1929). It is, therefore, probable that the border used here is contemporaneous with the British one. It is also a very convenient one, being a faunistic as well as lithological break of first order. In other parts of Scandinavian this break is not clearly defined, and it might be difficult to place the border exactly in some sections.

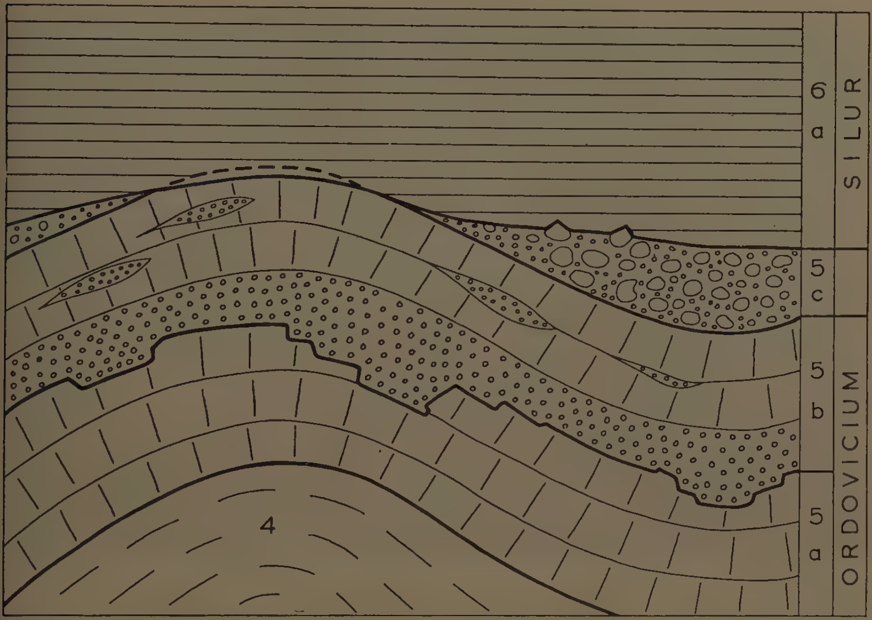

Fig. 1. Diagram showing the formation of the 5c conglomerate and the conglomerates in 5b. In the Oslo District there is generally no thick conglomerate beds at the base of 5b, but they are common in Asker.

The contact between the Ordovician and Silurian in the Oslo District is by most authors regarded to be conformable. KIÆR (1902) showed, however, in an ingenious way that stage 5b was folded below stage 6a. His maps of the facies in 5a and 5b showed that the areas with same facies were elongated, and parallel to the present strike of the beds, even when the compression of the later folding was compensated for. This shows that there must be an angular unconformity between 5b and 6a, even if he was not able to find it in the field.

The author succeeded in finding two localities in the Oslo District, in which the angular unconformity is clearly shown (see below). At the end of 5b-time, the beds were slightly folded in gentle syn- and anticlines, the latter reaching above the sea. The synclines between them were filled with coarse conglomerate, differing in groundmass from the common intraformational conglomerates in 5b. On this partly leveled surface the Silurian beds were deposited. Because of this structure, the angular unconformity is only observed in the flanks of the old (5b) anticlines, which often are distorted by later (Caledonian) folding, and Permian faulting (cf. text fig. 1). This is probably the reason why the unconformity has not been discovered earlier. It is worth mentioning that there are at least three types of conglomerates in connection with stage 5b. First at the base, often with erosional contact against 5a (in some localities in Asker, it seems as if the whole 5a is eroded away, and 5b rests upon 4d). This contact in some localities resembles an angular unconformity, but a closer examination always shows that the sections in question are in the slope of erosion channels in the older beds. The second type of conglomerate is the intraformational conglomerates, which are abundant in most localities, and which are most common in the upper part of the stage.

The third type of conglomerate is the filling of the synlines formed between 5b and 6a. In most localities it showns lithological differences from the other conglomerates.

LOCALITIES.

Alnabru. This locality is in the eastern end of a quarry just West of the railway and North of the main road (Strømsveien) at Alnabru. In the southern slope of the anticline (forming a prominent ridge in the landscape), the conglomerate is exposed. The angular unconformity between the base and the top is clearly demonstrated, towards the top of the anticline it thins out rapidly, and increases also in coarseness towards the syncline. The large, angular boulders might be more than one meter in diameter, and the matrix in the upper part of the conglomerate is formed by the Silurian shale. This indicates that the Silurian was deposited on a surface covered with large, loose boulders. This seems also to be the explanation why the nodular limestone band at the base of the shale is broken by one of the large protruding boulders. It probably reached above the bottom when the nodules were formed. No Permian faulting found in the section can explain the structure mentioned above.

Along the same anticline, there are several sections through the Ordovician/Silurian border, but in all these the massive limestone of 5b is followed by about ½ m of nodular limestone, and then dark,

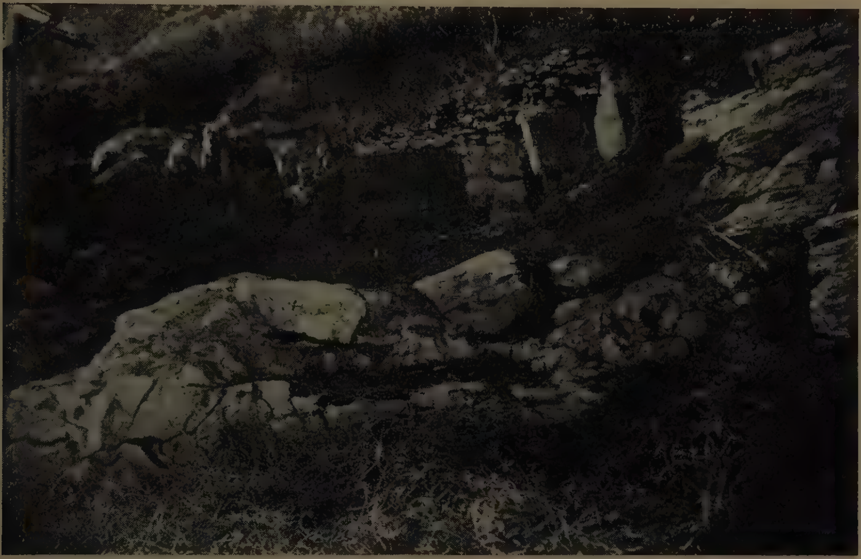

Fig. 2. The angular unconformity between 5b and 6a at the south-eastern end of Hovedøya. The conglomerate (5c) in the foreground, in the background the brownish calcareous sandstone (5c) with nodular limestone (6a) on top. Only some few meters to the right, the conglomerate has wedged out, and the sandstone is resting directly on 5b.

somewhat silty shales with some irregular siltstone bands. No trace of conglomerate is found, but the contact between the Silurian and the Ordovician indicates an unconformity, because the top of the limestone is distinctly eroded, and small-scale carst phenomena are quite common.

As mentioned above, the upper part of 5b consists of massive, partly oolithic limestones with few fossils. The lower part, the intraformational conglomerates and the border to 5a is not exposed.

Hovedøya. (Textfig. 2.) In this locality the contact between the Ordovician and the Silurian is exposed along the southern shore of the island, and shows very well the variations in the transitional beds. The locality was briefly mentioned by the author (SPJELDNÆS 1957), and a figure was given of the easternmost part of the section, where the angular unconformity is well developed. It is quite like that

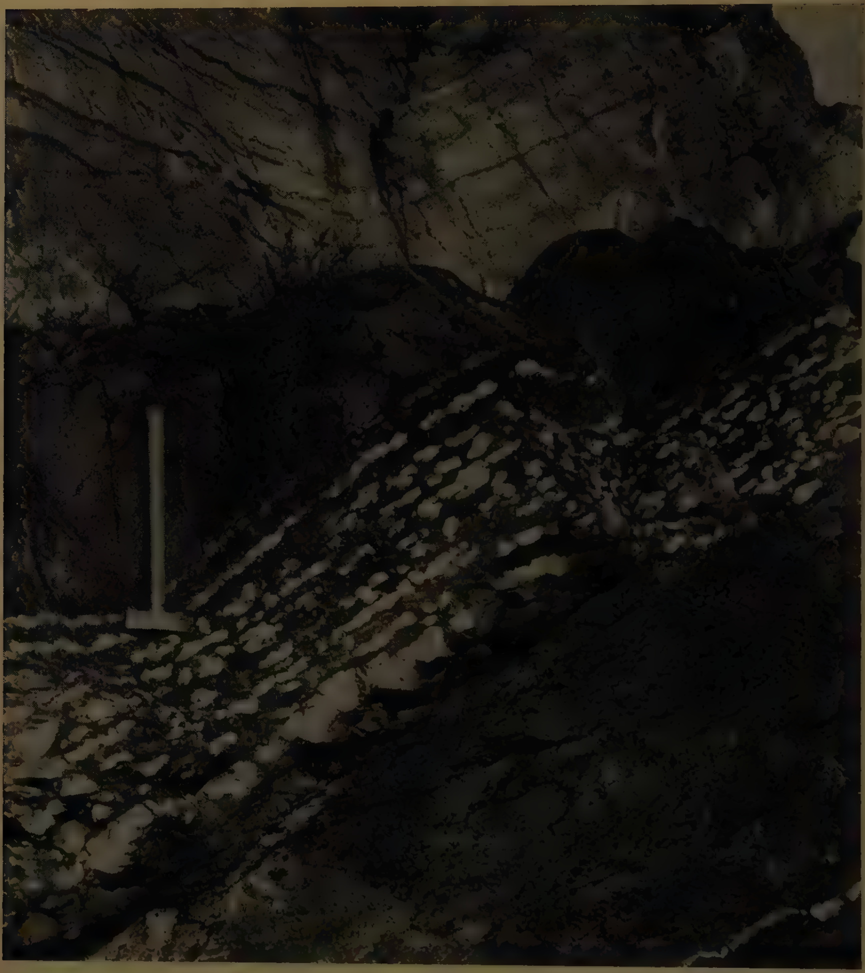

Fig. 3. The contacts 5b/5c/6a at the southern side of Hovedøya. The beds are inverted, so that the limestone seen on top is 5b, then with an interval of erosion 5c, and then with another interval the nodular limestone of 6a, followed by the sandy shale.

found at Alnabru, but in this case the conglomerate is not directly overlayered by the nodular limestone and shale. A thin bed (1–½ m) of brownish weathering calcareous sandstone is found in between. The matrix of the conglomerate is also the same sandstone. The

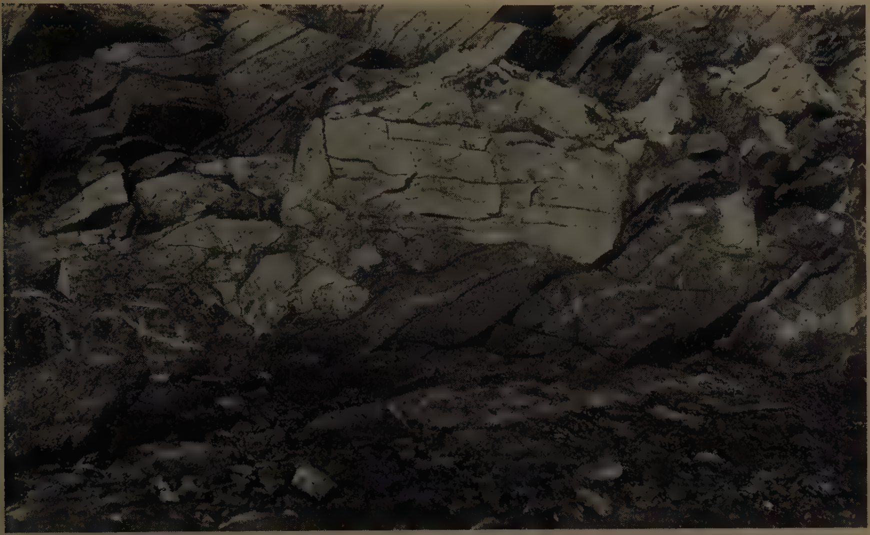

Fig. 4. The coarse conglomerate in 5c at the south-western end of Hovedøya. The largest boulder on the picture is 1½ m long. The beds are inverted, and the conglomerate is filling a small valley in 5b.

conglomerate itself is only exposed in a cliff at the shore, and only some few meters higher up along the flank of the anticline, the nodular limestone is resting directly on the massive limestone of 5b with erosion contact.

To the West the beds are inverted, so that the massive limestone is found above the Silurian. No conglomerate is found, except on the westernmost end of the island. The sequence is first massive limestone, then (with erosion-contact) the brown, calcareous sandstone, and then, possibly also with an unconformity, the nodular limestone, which form the base of the Silurian (textfig. 3). The surface of the 5b limestone is generally very even, but small irregularities occur in some places.

At the westernmost end of the island, the brownish sandstone grades into a coarse-grained limestone-conglomerate, which forms a channel in 5b. The boulders in the conglomerate are of variable size, most of them are small, but in some lenses they are very large, up to 1,5 m in diameter. They are angular, and consist mainly of different types of massive limestones from 5b. Most of the limestone boulders seem to be derived from the sides of the erosion cannel, but other types are also found, some of which are met with in 5b in other localities (textfig. 4).

Especially in the finegrained beds of the conglomerate, many fossils are found. They seem to be of the same type as those found in 5b, but the fauna is not yet studied in detail. Any great difference from the fauna in 5b can not be expected, because of the small difference in time and the similarity in facies. Members of the fauna in the lowest Silurian is probably absent because of the striking difference in facies (limestone with no or little clay, and dark, lime-free silty shales). Among the fossils found in these beds are *Graptodichtya proava* (EICHWALD), which is common in the upper part of 5b, and also is found in the upper part of the Dalmanitina Beds in Sweden, and in the Porkuni Beds in Esthonia.

STRATIGRAPHY.

The stratigraphy of the uppermost Ordovician and the lowest Silurian in the Oslo District has been studied especially by BRØGGER (1887) and KIÆR (1908). Much more studies are, however, necessary in order to get an opinion of the stratigraphy and sediment petrology of this district.

Just as in Asker (cf. KIÆR 1902), the facies is very variable both in 5a and especially in 5b. Generally it seems as if the sediments as a rule are coarser and more calcareous in the Oslo District, and the range of different types of sediments is not so wide as in Asker.

In most localities the transition between 5a and 5b is gradual, without a conglomerate. Just above the base of 5b, a peculiar bed is found. It is about ½ m thick, and consists of sandy limestone with a crumbled bedding, indicating a formation by subaqueous slides. This thin horizon is, however, remarkably persistent, and seems always to occur in the same stratigraphical position (textfig. 5). The origin of the bed is therefore unknown. In the higher parts of 5b there are generally conglomerates. In some localities there are only very few beds of conglomerate, and in others they form the larger part of the sequence.

All the conglomerates are of the same type; they occur as lenses,

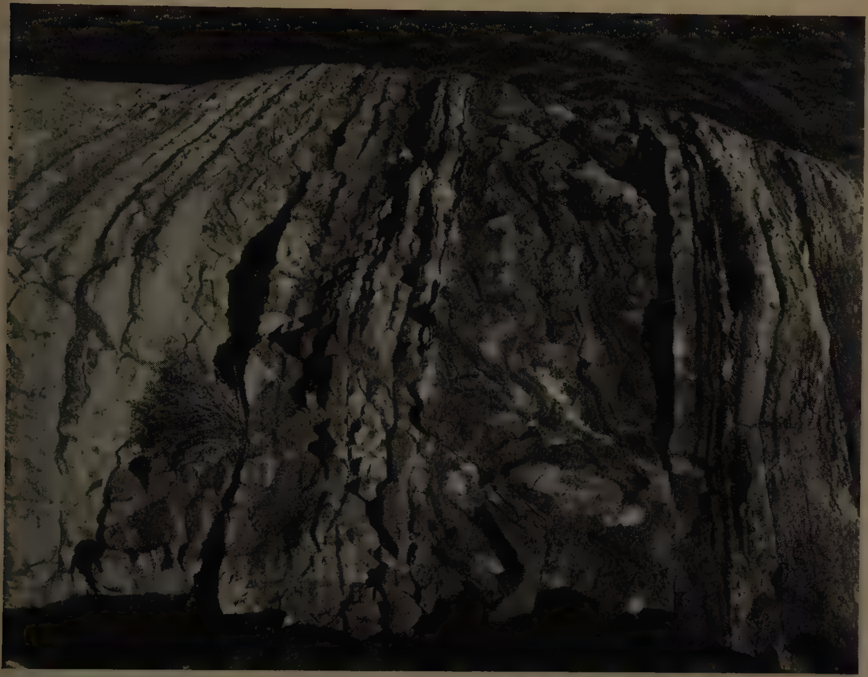

Fig. 5. Sandy limestone bed with disturbed bedding, from the lower part of 5b, at the eastern end of Rambergøya. The bed is 60 cm thick in this locality.

generally with cross-bedding (textfig. 6). The boulders are well rounded, of uniform size, and consist of limestones and rolled fossils, mainly corals. Most of the fossils found as boulders are from 5a; in fact the guide fossil for this zone, *Sarcinula organum* is very common. Algal limestones with *Rhabdoporella* and *Vermiporella* are also common. This is remarkable, because these fossils, which are very common in 5a in Asker are not found in 5a in the Oslo district. The well rounded boulders also indicate a long transport of the material.

The matrix of the conglomerate, and the beds in between the conglomerates consist generally of sandy limestones, which often are so rich in sand that they should be classified as calcareous sandstones.

The sand in this rock is unusual, as some of the grains, smaller than 0,3 mm, are angular, and the larger ones (½–4 mm) are very well rounded; in fact most of them are nearly perfectly sphaerical.

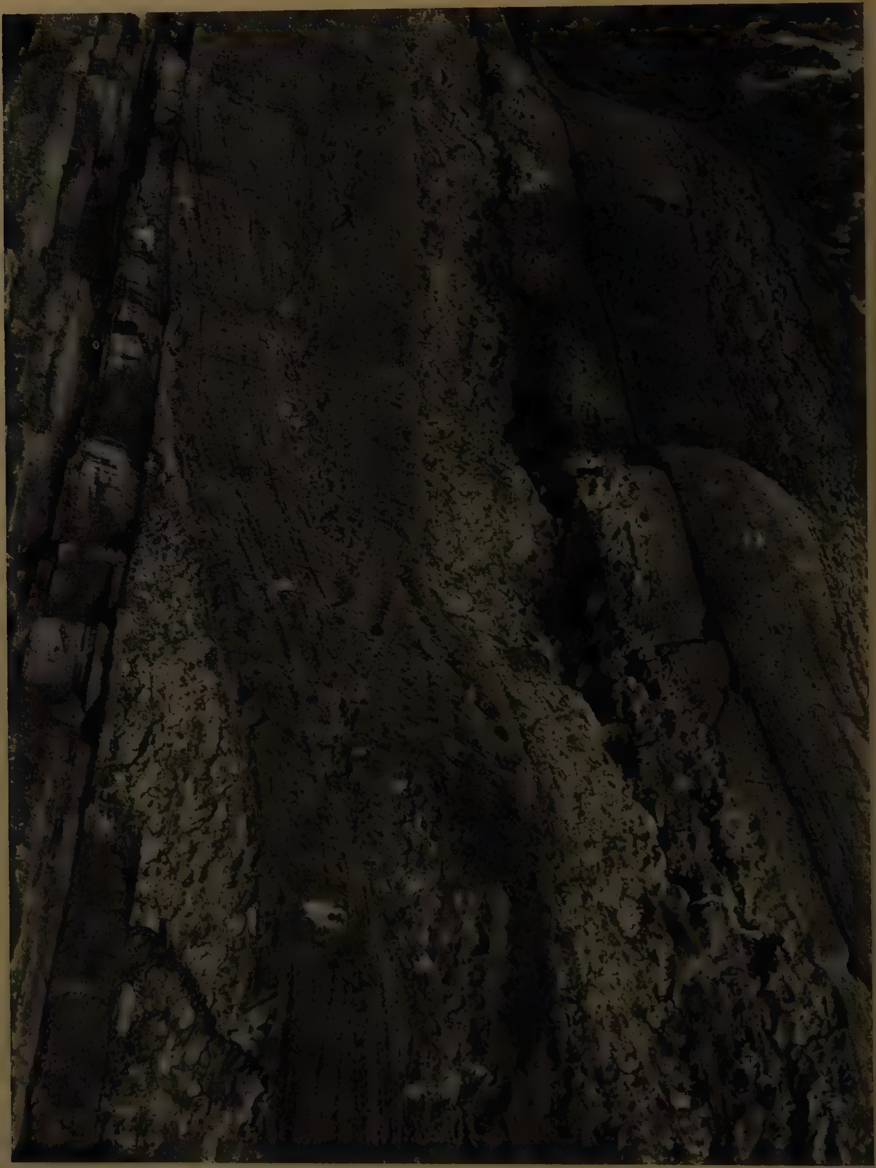

Fig. 6. Conglomerate beds in the upper part of 5b, at the southern side of Rambergøya. Note the slight unconformity in the foreground to the left. The beds are inverted, so that the upper beds are to the right.

The larger grains have also a «frosted» surface, and might be eolian. In some localities, especially at Bjerkøya in Asker, the beds show well developed crossbedding, resembling that of dune sands. One argument against the interpretation of these rocks as eolian sediments is that the smaller quarts grains do not seem to be eolian in origin (angular, and without frosted surface), and that the velocity of wind necessary to move quarts grains of this size (½–4 mm) through the air is too high to be a constant feature under normal conditions. A detailed study of the origin of these sediments is outside the scope of this paper, and the features are only mentioned to give an impression of the type of sediment found.

All the rocks, even those very rich in quarts have calcareous cement, and oolithes are common. Fossils are not common, except as boulders in the conglomerate, and in finegrained beds where the supposed eolian grains are not found.

Above the typical 5b the unconformity is found, and even in the localities where it can not be seen to be angular, the top is eroded. The beds between 5b and the typical Silurian (6a) are rather characteristic, and because of the important border between them, a new term, 5c, is introduced for these beds. They are defined as the beds resting with erosional contact on 5b, forming the wedges of sediment between 5b and 6a. It represents a very short time interval, and it is difficult to refer it to the Ordovician or Silurian. It is formed after or during the folding, appearently conformable with the Silurian, and disconformably above the Ordovician (5b). On the other hand, it has the same facies as the Ordovician, and differs strongly in lithology from the Silurian. The paleontological dating of the beds are based on the find of graptolites in the lowest part of 6a, and this graptolite indicate the very base of the Silurian. 5c is therefore with a query included in the Ordovician. The angular disconformity is then not exactly at the border between the Ordovician and Silurian, but just below it, in the topmost Ordovician.

The basal beds of the Silurian are generally developed as a thin (½ m) nodular limestone, followed by sandy shales with siltstone bands from 2–15 cm thick. The siltstone bands often show graded bedding, which might be due to turbidity currents, possibly from the flanks of the Ordovician anticlines toward the bottom of the synclines.

The thickness of the beds in the Lower Silurian is variable, and considerable differences in facies are found in different localities. KIÆR (1908) described some of the sections in detail, and divided the beds into zones, 6aα, 6aβ, 6bα, 6bβ, 6cα, 6cβ. There are no sharp faunistic and lithological limits between these zones; the content of carbonate increase towards the top, and the fauna is also much richer in the upper zones than in the lower.

A detailed study of KIÆR's sections shows that his zone 6aβ is only found on the northernmost islands in the Bunnefjord, and in these localities the typical 6aα is missing. This is developed only in the southern islands in the Bunnefjord, Malmøya and Ormøya.

A comparison of the faunas in 6aβ and 6bα indicates that these zones are identical, and that the terminology has to be slightly revised. 6a is reserved for the thick siltstone-shale beds found only on the southern islands. It is not subdivided; further studies of the graptolites might give good subzones. 6bα is used for the fossiliferous shales with some few siltstone beds, and some nodular limestone beds in the upper part.

The difference in facies in 6a–b might be explained in two ways. Either the Silurian sea transgressed northwards, and reached the northern islands later than the southern ones. Or the sections on the southern island are more in the middle of synclines where the beds are thicker, either due to contemporaneous folding, or because the 5b-anticlines were still topographical ridges.

The features in the areas to the north and west seem to indicate a transgression, but it might also be a combination of both.

In the mainland in Oslo (Alnabru) the development is exactly similar to that in Hovedøya, and in Asker the beds described as 6aα and 6aβ by KIÆR (1908) have the same fauna as 6b in the Bunnefjord area. This might also be interpreted as a calcareous facies of 6a, but this is not supported by any paleontological data.

North of Oslo, in a railway section between Gulleråsen and Gråkammen, 6b is resting directly on the eroded surface of 5b.

In the Ringerike district, KIÆR (1908) also described beds as belonging to zones 6aα and 6aβ and also 6b and 6c. Even in the beds designated 6a, one finds fossils which are guide fossils for 6c in the

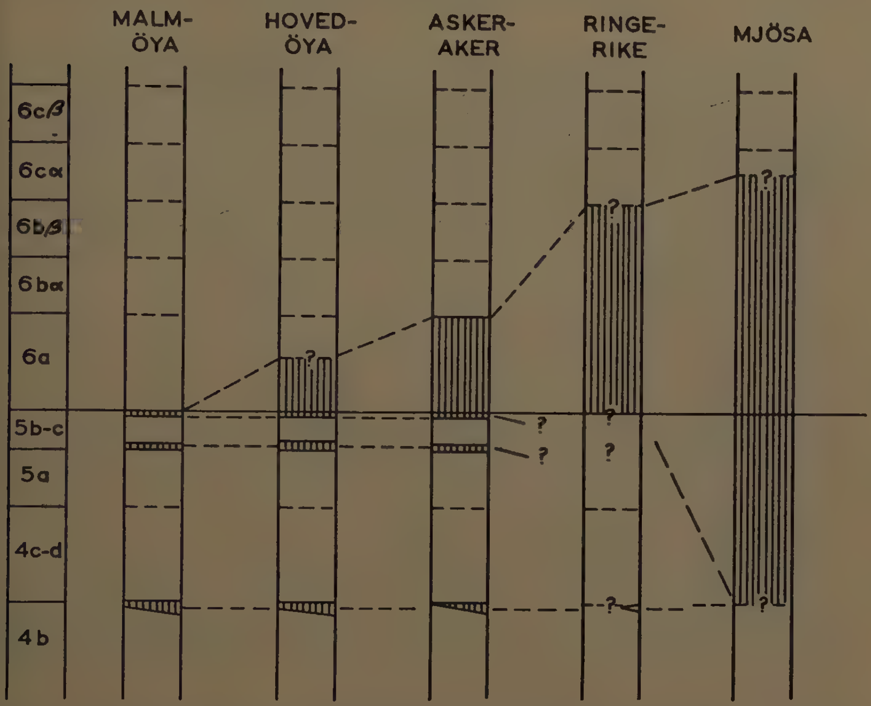

Fig. 7. Diagram showing the development of the Upper Ordovician and Lower Silurian in parts of the Oslo Region.

Oslo–Asker districts (*Rhinopora malmoeensis* and Stropheodontids). This indicates that the zones 6a and possibly also 6b are missing in Ringerike.

In Hadeland a thick, unfossiliferous sandstone is resting on 5a, and the oldest fossils found above it belong to 6c (cf. MAJOR 1946). In the Mjøsa district, the oldest Silurian belong to 6c, and is resting on the Middle Ordovician Mjøsa Limestone (textfig. 7).

This seem to indicate that the base of the Silurian is younger towards the north, and that the most complete sequence is found in the south-east (Malmøya).

No names are given to the lithostratigraphical units at present; — much detailed studies still have to be made in this area.

TIME AND STRENGTH OF FOLDING.

The presence of an angular unconformity just below the Ordovician-Silurian border in the Oslo district was obscured by the presence of two phases of folding, with the same direction, one in the uppermost Ordovician and one post-Silurian. Because the two foldings were in the same direction, it is difficult to estimate the relative strength of the two orogenies.

It has repeatedly been noticed that the Ordovician beds are stronger folded than the Silurian ones in the Oslo Region, but this is generally ascribed to the fact that the Ordovician beds mainly consist of shales which are more easily folded than the more competent, massive limestones in the Silurian. The latter are supposed to show a «Schuppen» — structure. The presence of the angular unconformity described here offers an alternative explanation; that the Ordovician beds were folded before the deposition of the Silurian.

The angular disconformity is generally very slight, 10–20° at most. This seems to indicate that the folding was very slight, and in this case it could not explain the difference in folding between the Ordovician and Silurian.

It is, however, probable that the folding took place both before and after the unconformity was formed. In the Oslo Region the beds were folded during rather rapid sedimentation, and unconformities will not be found, because each step in the folding is immediately compensated by sedimentation and erosion. Even if, theoretically, numerous angular unconformities are present, they are all too small to be detected. Only when the sedimentation is stopped, such as at the top of 5b, there will be time enough for developing a visible angular unconformity.

The coarse sediments, and the irregular development of the facies both in 5a and 5b (cf. KIÆR 1902, figs. p. 48–50) indicate that the folding started already in 5a, reached a maximum in the top of 5b, and continued also in 6. The numerous beds with graded bedding in 6a and the base of 6b also indicate that the folding continued up to this time, and in 6c at Sælabonn in Ringerike, there are signs of subaqueous slides.

It is therefore possible that the Ordovician-Silurian folding was

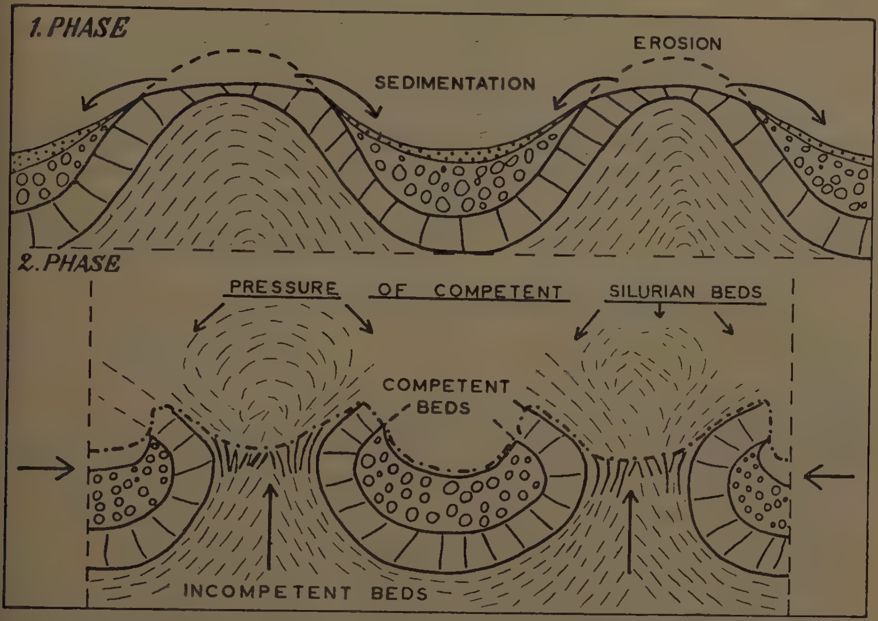

Fig. 8. Diagramatic figure illustrating the author's theory of the formation of the overfolded anticlines in the Bundefjord district by two phases of folding. For explanation see the text.

considerably larger than it appears from the size of the angular unconformity. It is also an interesting question if the directions of the two phases of folding were exactly the same, or if they differed slightly. This latter possibility might explain some of the irregularities of the folding in the Oslo Region. It is, however, outside the scope of this paper to deal with that problem.

The special style of folding found in the Bunnefjord area, (cf. Brøgger 1887) might be explained by the double folding. In this area all the anticlines are overfolded, either to the southern side, or to both sides. The anticlines consist of Ordovician shales, and the partly closed synclines of Silurian beds, and the massive calcareous beds of 5b. The sections mentioned from Hovedøya indicate that the anticlines were formed already in the Ordovician, and that their tops vere eroded before the deposition of the Silurian. The synclines were filled with sediments, generally very competent beds.

When the post-Silurian folding started, the area consisted of bands of competent beds (former synclines) and incompetent ones (former anticlines). By the folding, the soft beds in the anticlines were squeezed up, and folded over the more competent beds in the synclines (textfig. 8). This is an example of one of the feature in the folding in the Oslo district which is difficult to explain if it is supposed that there was only one phase of folding, but is easily explained by the presence of two phases of folding.

It is also interesting to note that the phase of folding continued for a long time, in contrast to the statements given by STILLE (1924, 1950). Features similar to those in the Oslo district shown by folding during sedimentations are described by KREJCI-GRAF (1950). It seems, therefore, to be established that the phases of folding were not very short, abrupt events, but that they developed slowly, through millions of years.

In the usual terminology of orogenic phases, this folding should be termed the Taconic. This folding is supposed to be found at the border between the Ordovician and Silurian. In the Oslo Region this is almost correct, but in Wales (Llandovery district, cf. JONES 1925) there are three phases in the lowest Silurian, and in central Scandinavia, it is deeper in the Ordovician (in Northern Sweden KULLING (1933) reports *Holorhynchus giganteus* and other 5b fossils from above the Voitja conglomerate, which possibly marks the folding).

This indicates that the orogenies at least in some cases are not contemporaneous in all areas, even if their maxima seem to fall within a rather short period. This period is, however, of the order of size as the Ashgillian or Llandoverian.

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NEW RESTORATIONS OF THE HEADS OF *PHARYNGOLEPIS OBLONGUS* KIAER AND *PHARYNGOLEPIS KIAERI* SP.NOV., WITH A NOTE ON THEIR LATERAL-LINE SYSTEMS

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Introduction

The work on which this paper is based forms part of a wider study of the Norwegian and Scottish genera of the Order Anaspida, and arises out of an attempt to use the Norwegian material as a standard of reference for the less well preserved Scottish forms, *Birkenia* and *Lasanius* (TRAQUAIR 1899, 1905), and more directly from an attempt to resolve the structure of the dermal cranial roof and to locate the nasohypophysial and pineal foramina in *Birkenia*. In the course of this work it has become apparent that new descriptions of the cranial roof of the Norwegian Anaspids are required: in this paper the cranial roof of one genus, *Pharyngolepis*, is re-described together with a description of a newly recognized species, *Pharyngolepis kiaeri* sp. nov.

The Norwegian genera, *Pharyngolepis*, *Pterygolepis* (=*Pterolepis*) and *Rhyncholepis*, were very carefully described by KIAER in his original monograph on these forms, (KIÆR 1924) but until recent times no further work has been done on them and, indeed, very little on Anaspid morphology in general. STENSIÖ (1939) reviewed the existing knowledge of the group fairly extensively in a paper dealing with a newly discovered Canadian Anaspid, *Endeiolepis*, and also earlier in «The Downtonian and Devonian Vertebrates of Spitsbergen — Cephalaspidae» (STENSIÖ 1927) and in «The Cephalaspids of Great Britain» (STENSIÖ 1932). In a new work, STENSIÖ (1957) has discussed many aspects of Anaspid morphology of general importance from the point of view of their status as Ostracoderms and has given new restorations of the head and branchial regions of *Pterygolepis* in particular, which must certainly form the basis for all subsequent work on other Anaspids.

The histology of the Anaspid exoskeleton was described by GROSS (1938) in a valuable contribution dealing mainly with detached scales from the Downtonian of S. Wales, and ROBERTSON (1937) has described still older scales from the Ludlow of Oesel; but the scales of Anaspids are, as a rule, too badly preserved for a general histological survey of the order to be made. For example, little or no structural detail can be made out in the scales of any specimen of *Birkenia* yet examined (TRAQUAIR 1899; STETSON 1928). It is clear, however, from earlier work and from sections which have recently been prepared by Dr. T. Ørvig and the writer that *Pterygolepis* scales resemble those of the Welsh and Oesel material quite closely (Plate VI). There is every reason to believe that the very slight degree of ossification in the greater part of the exoskeleton of *Lasanius* and the apparent absence of all dermal bone in *Endeiolepis* is no more than an extreme manifestation of the tendency towards exoskeletal reduction which is characteristic of the Anaspia as a whole (STENSIÖ 1939), that *Lasanius* and *Endeio-*

lepis are, in other words, very specialized and not primitive (c.f. KIAER 1924; STENSIÖ 1927). A closely parallel case is seen in the Pertromyzontids which, although related to both the Anaspids and the Cephalaspids, must have taken their origin quite early from some intermediate ancestral group (probably nearer to the Cephalaspids than to the Anaspids) and which subsequently underwent, in many respects, a reductional evolution developing, or accentuating, many characters similar to those of the Anaspids (see STENSIÖ 1957).

Since TRAQUAIR's original description (TRAQUAIR 1899) *Birkenia* has been re-examined on very few occasions (STROMER 1926, 1930; STETSON 1928) which is not surprising in view of the difficulty of the material. This species is not uncommon but is normally poorly preserved — as impressions or highly carbonized compressions, almost always lateral. KIAER (1924) rightly considered that in the arrangement of the plates and scales of its exoskeleton, *Birkenia* is much more complex than any of the other known armoured Anaspids; nevertheless, with regard to the pattern of the cranial roof and the presence of a discontinuity in the dorso-lateral squamation of the trunk, this genus seems to have much in common with *Pterygolepis* — perhaps enough to justify the inclusion of *Pterygolepis* in the family *Birkeniidae*, or in a super-family *Birkeniformes* (c.f. KIAER 1924; STENSIÖ 1957). It is already clear that STETSON's reconstruction of the cranial roof in *Birkenia* is inaccurate, notably with regard to the position of the nasohypophysial and pineal foramina. The foramen which STETSON called the «nostril» is almost certainly the pineal foramen and his «pineal opening» is probably an artefact; nor is the shape of the «pineal plate» in his drawing quite correct, it is actually much more like that of *Pterygolepis* (see KIAER 1924). The trunk squamation of *Birkenia* has several hitherto unrecognized peculiarities in the orientation of the scales in various areas, this is important because of the association between the arrangement of the scales and the arrangement of the myotomes. This matter will, however, be considered more fully on another occasion and before a new restoration of this important species is completed, some new material is urgently needed since, apart from the generally poor preservation, many of the existing specimens are badly weathered and covered with a thick layer of «rust».

Materials and Methods

The specimens examined in the course of this work consisted of a large collection of the genera of Norwegian Anaspida mostly belonging to the Palaeontological Museum, University of Oslo and a few to the Swedish Museum of Natural History, Stockholm. In addition, I had at my disposal another large collection of the two Scottish genera of Anaspida borrowed from the Royal Scottish Museum, Edinburgh; the Geological Survey; Edinburgh; the Kelvingrove Museum, Glasgow; the Hunterian Museum, University of Glasgow; and the Palaeontological Institute, University of Uppsala. I am most grateful to the authorities of all these museums and institutes who have so generously allowed me the use of some or all of their Anaspid collections. With one exception, certain specimens of Norwegian Anaspids only are described and figured in this paper, their catalogue numbers appear in the appropriate sections.

All the Norwegian Anaspid material originated from the Rudstangen (? Downtonian) locality at Ringerike, S. Norway, and the rock in which they are preserved is a very fine-grained, greenish-grey sandstone. The fossils are always strongly compressed and are sometimes quite flat (see KIAER 1911). Remains of exoskeletal material are usually present in a brown, translucent form in which, in most cases, little histological detail can be made out.

The Scottish material is derived from several (? Downtonian) localities in Lanarkshire, Ayrshire and Dumfries-shire in the south of Scotland (see TRAQUAIR 1899; PEACH & HORNE 1899). They are present in rock which varies from light-coloured, rather loose sandstone to fine-grained, light to dark grey or almost black shales.

The fossils were examined in strong illumination with a binocular loupe using 95 % alcohol, xylol or oil of aniseed as wetting fluids. Photographs of suitable specimens immersed in xylol or oil of aniseed were taken under powerful arc-lamp illumination at magnifications depending on the size of the specimen and the area under investigation. In many cases, a red filter was used in conjunction with a small apperture on the camera, and a prolonged exposure (up to two hours) was given in order to reduce all uneven reflections from the matrix to a minimum and to enhance details on the fossil as far as possible. The photographs, printed on suitable matt paper, were outlined in indian-ink and difficult details were added from inspection of the fossil under the binocular loupe; the outlined photograph was then traced, and on such tracings the restorations figured in this paper are based. To obtain an estimate of the perspective foreshortening, the restorations were further traced on to thin wax-sheets which were then empirically moulded into the supposed shape of the cranial roof in its natural condition, these models were photographed in plan and side elevation and drawings were made from them.

Little or no preparation of the material was required although it was necessary to clean parts of some fossils with fine needles under the binocular loupe.

The work was carried out entirely in the Palaeozoology Department of the Swedish Museum of Natural History, Stockholm and I am most grateful to Professor E. A. Stensiö for all the help and facilities which were given me during my visits.

The Cranial Roof of *Pharyngolepis*

Because of the impossibility of homologizing the plates of the cranial roof in Anaspida with those in Cephalaspida or any other group of lower vertebrates, the dermal plates of the cranial roof in *Pharyngolepis* (except the numerous small scales in the occipital division) are designated by means of letters, thus G to Z with e.g. K and K^a etc. where a plate is apparently subdivided longitudinally; and K, K_2 etc. where a plate seems to be divided transversely by a groove or sensory-line canal. This is possible because, whilst two species are involved, the form and arrangement of the plates is fundamentally the same in both. Whilst this lettering of the plates is necessary both to describe the sensory-line system and to compare the cranial roofs of the several specimens, it must be emphasized that it has no morphological significance in itself and is not intended to imply any homologies whatever outside this particular genus. It is hoped, however, that studies now proceeding will enable at least some true homologies to be established amongst the Anaspid forms; in this connection the recognition of parts of a sensory-line system in *Pharyngolepis* has an added importance. STETSON (1928) and, to some extent, KIAER (1924) have given names to certain plates on the cranial roof of Anaspids but, for the reasons given above, these systems of nomenclature must be regarded as unsound at present.

Text Figures 1 A and 1 B are drawings of the cranial roofs of two specimens of *Pharyngolepis oblongus* and Text Figure 2 is a drawing of the only example of *Pharyngolepis kiaeri*. All three figures have been made directly from the photographs of the fossils and represent the dermal plates in basal (internal) view, horizontally flattened. The diagnoses of the two species are based on these figures and on the unrestored photographs (Plates I–IV). It is interesting to compare Text Figures 1 A and 2 with Text Figures 3 A, 3 B, and 4 A, 4 B in which an attempt has been made, with the use of wax-plate models, to restore the cranial roof, in dorsal and lateral aspects respectively, of the two species. In the restorations the differences between the species are emphasized and, in addition to other features, the relatively short pre-nasal and long post-nasal divisions of the cranial roof in *Pharyngolepis oblongus* contrast sharply with the relatively much longer pre-nasal division, and the relatively shorter post-nasal division of *Pharyngolepis kiaeri*.

The individual plates and scales are not here described in detail since their form and arrangement will be sufficiently clear from the figures, and the diagnoses draw attention to points of special importantance. It is, however, of value to make a brief comparison of the new restorations with those figured by KIAER (1924, Fig. 20, p. 44; Fig. 26b, p. 55). It is at once obvious that KIAER was unsuccessful in resolving plates *S*, *T–T*, whilst plates *U* and *V* are incorrectly drawn for the following reason: in Specimen E. 1039 (KIAER 1924, Fig. 20) the bone substance that is actually preserved does indeed make a deep caudal notch in plate *V* and, at first sight, this seems to be the limit of the plate. But, in fact, the suture lies more anteriorly leaving a broad V-shaped area posterior to the suture from which the bone has disappeared. It is also clear from Fig. 26b that KIAER did not correctly identify the pineal foramen but confused it with the opening that is actually the nasal part of the nasohypophysial foramen; nevertheless, reference to KIAER's Figure 20 shows that he did observe the true pineal foramen. The anterior margin of the hypophysial part of the nasohypophysial foramen in KIAER's Figures 20 and 26b has been given an arched form instead if the practically straight margin which is correct; once again the error can be traced to Specimen E. 1039 in which this margin is damaged. I have found no justification for the rather regular, lozenge-shaped occipital scales illustrated by KIAER in Figure 26b, it is certainly possible that from the exterior side they had this appearance but the only available specimens with this part of the cranial roof in a well preserved condition display the basal (internal) faces of the scales, and in this aspect they are somewhat irregularly rhomboidal and closely fitting without, as far as one can judge, any overlapping. Another matter of some importance is that, as noted by KIAER, the circum-orbital plates have a thickened basal (internal) ridge surrounding the foramen; but from KIAER's Figure 26b these ridges could be mistaken for a ring of separate elements — such a mistake seems already to have occurred (see BYSTROW 1955, Fig. 39, p. 513). Whether a sclerotic ring was also present is still questionable. It also seems now quite certain that KIAER's restoration (Fig. 26b) contains features of both *Pharyngolepis oblongus* and *Pharyngolepis kiaeri*, this is again referred to on p. 384.

Finally, a few comments on the nature of the sutures and grooves between the plates and scales of the cranial roof and adjacent areas may usefully be made. Between plates Q and Q^a there is a very deep groove, probably separating the plates completely; basally (internally) there is a ridge along each side of this groove. It would be incorrect to regard this groove as a suture corresponding, for example, to those between plates U and V; Q^a and V etc. It does, however, seem to correspond to the grooves between plates X and W (which also have a thickened ridge of bone along their common margins), G and P, O and K, and probably to that between J, K, L, M and J_2, K_2, L_2, M_2 (see Text Figure 2) etc. Plates R and R^L are loosely articulated together and the suture between plates R^L and X was probably not rigid, thus suggesting a certain flexibility of the snout region; a flexibility of this kind is in agreement with STENSIÖ's view that the Anaspids had suctorial mouths.[1] The V-shaped groove in plate H, the groove between plates Q and Q^a, and that running transversely from plate H to the lateral margin of the cranial roof are all constant features of all the specimens of *Pharyngolepis* examined (see further the note on the sensory-line system).

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[1] STENSIÖ (1957) points out that the mouth cannot have been fringed, as in e. g. KIAER's reconstructions of the Norwegian Anaspids, by free margins of bone, either cranial elements or ventral visceral scales; but there must have been soft tissues extending past the bone margins to form an oral opening. In the absence of any true jaw elements, a suctorial mouth with or without a rasping tongue is a strong probability for all Anaspids.

All other details may readily be understood from the figures, diagnoses and descriptions of the species.

Descriptions of the species

PHARYNGOLEPIS OBLONGUS KIAER (Text Figures 1A, 1B, 3A, 4A, 5 and 6; Plates I–III) *Diagnosis:* — orbital openings anterior to the mid-transverse line of the bony skull roof; the entire nasohypophysial foramen situated between the orbits. Occipital division of the cranial roof with numerous, irregularly rhomboidal scales; ill-defined and

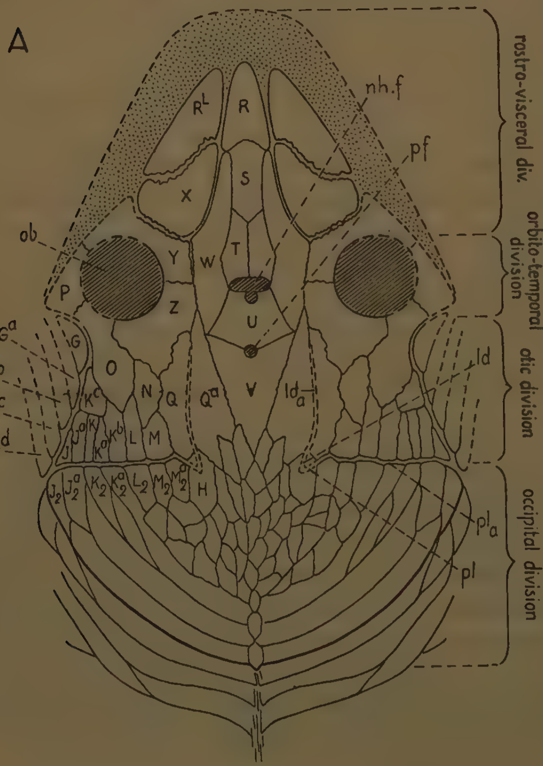

Fig. 1 A. Pharyngolepis oblongus KIAER; dermal cranial roof of Specimen E. 0122 (Pal. Mus. Oslo — counterpart of the lectotype) flattened in the horizontal plane and seen in basal (internal) view. The stippled area indicates soft tissues extending beyond the margins of the plates and scales. The major exoskeletal plates are lettered *G* — *Z* as explained in the text and the four divisions of the cranial roof are indicated; other letters, *ld* and ld_a = cranial part of the dorsal lateral-line groove; *nh.f* = nasohypophysial foramen; *ob* = orbit; *pf* = pineal foramen; *pl* and pl_a = posterior pit-line groove. (see also Plate I). X 2.7.

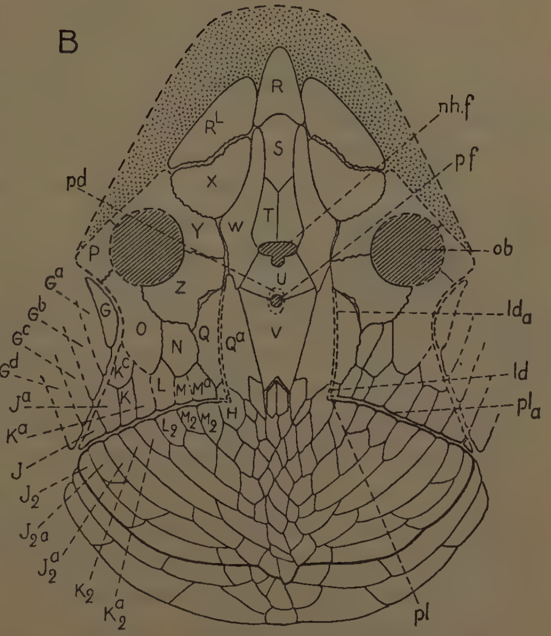

Fig. 1 B. Pharyngolepis oblongus Kiaer; dermal cranial roof of Specimen E. 1039 (Pal. Mus. Oslo) flattened in the horizontal plane and seen in basal (internal) view. (see also Plate II). X 2. *pd* = pineal depression; other lettering and shading as in Text Fig. 1 A.

rounded posteriorly. Plates bordering the groove between the otic and occipital divisions of the cranial roof considerably more subdivided than in *Pharyngolepis kiaeri*, never fewer than 5 and frequently as many as 7. The lateral postorbital emargination of the cranial roof is filled by several (about 5) separate plates (the *G* series). The ventrolateral scales of the cheek and ventral visceral exoskeleton (see Text Figure 5) large, rhomboidal, increasing in size ventrally and, especially, posteriorly.

In addition there are several other specific characters of *Pharyngolepis oblongus:* measured on the flattened head, the greatest width of the cranial roof is between plates J_2–J_2 in the occipital division posterior to the transverse groove pl_a separating the otic and occipital divisions of the cranial roof. The rostral part of the rostro-visceral division is narrow, broadening out nearly uniformly to plates *P–P* in the orbito-temporal division at an angle of 74° to 78°. Plate *U* is large and meets Q^a laterally, plate *V* has acute anterior angles. The apex of the V-shaped groove in plate *H* lies one third, or a little more, of the distance from the posterior to the anterior end of the cranial roof. The length to breadth ratio of the plate complex *R*, *S*, *T*, *U*, *V*, *W* is about 3 : 1, of plate *R* it is between 1¾ and 2 : 1, of plate R^L it is about 2½ : 1, and of plate *X* about 1½ : 1.

Lectotype: — a large and well preserved specimen with the dorsal side of the head and trunk exposed in basal (internal) view, Specimen E. 1152 (Pal. Mus. Oslo) figured by KIAER 1924 in Plate VIII, Figure 1, and Plate IX, Figure 1; and the counterpart of E. 1152; Specimen E. 0122 (Pal. Mus. Oslo), figured in this paper in Plate I.

Material: — in addition to the counterpart of the lectotype, two other specimens of *Pharyngolepis oblongus* which display parts of the head region have been available for study; they are E. 1039 (Pal. Mus. Oslo), figured by KIAER 1924 as Figure 20, p. 44 and in this paper in Text Figure 1A and Plate II. It consists of part of a cranial roof, mostly median to the orbital foramina with a small area of the squamation of the right cheek. The other specimen is E. 1068 (Pal. Mus. Oslo) figured by KIAER 1924 in Plate IX, Figure 2 and Plate XI, Figure 1; and in this paper in Text Figure 5 and Plate III.

Description. All three specimens are rather large but E. 1039 is the biggest and its estimated length, based on the head length, is in the region of 250 mm; KIAER's figures for the total length of *Pharyngolepis oblongus* range from 190 to 200 mm only. The length of the head of E. 1039 is approximately 38 mm, the width across the orbital division at its widest part is about 23 mm, from the tip of plate *R* to the anterior margin of the orbit is about 14 mm; from the tip of plate *R* to the pineal foramen, 17 mm; and to the angle of the V-shaped groove in plate *H* about 24 mm. Plate *V* in this specimen has an unusual shape, its posterior end is notched, giving rise to a «butterfly-like» appearance — two small, rhomboidal scales fit into the notch. The anterior occipital scales in this specimen are, on the whole, much more regular than in any of the others — but this is perhaps a function of its size or age. The pineal opening has the same relative position and size as in the other specimens but it can be seen here that, viewed from the interior of the head, the actual foramen pierces a larger, oval, longitudinally arranged depression which must have contained the bulk of the pineal body (Text Figure 1B, *pd*).

Specimen E. 0122 is a counterpart bearing the dorsal side only of the head and body (the tail is missing) of a *Pharyngolepis* whose total length is estimated at about 193 mm (the preserved part measures 145 mm) in which the scales and dermal plates are mostly present but in a considerably altered condition as far as their composition is concerned. The length of the cranial roof is 29 mm, the estimated width across the orbito-temporal division is 19.5 mm; the maximum width of the cranial roof is 20.5 mm. The length from the tip of plate *R* to the anterior margin of the orbit is 10.25 mm, the length from the tip of plate *R* to the pineal foramen is 14 mm, and to the angle of the V-shaped groove in plate *H* 20.25 mm. From this specimen one can gain an excellent idea of the dorsal aspect of *Pharyngolepis oblongus*; the dorsal scales lie in a practically parallel-sided strip from just behind the cranial roof to the end of the series of dorsal ridge scales, and have a nearly constant breadth of 21 mm. If we allow for the natural arching of the dorsal scales, which are here laid almost flat, we obtain a picture of a parallel-sided, rather narrow-backed form — in this case the breadth across the back could have been no more than 17 or 18 mm, possibly less.

Specimen E. 1068 (Text Figure 5) provides an interesting comparison with the previous specimen, here the animal is preserved in a lateral compression with only the right and central median part of the cranial roof flattened out horizontally; it is a little smaller than E. 0122, i.e. about 188 mm. From the branchial region to the anal fin the depth is fairly constant at 35 mm, the thickness of the compression is only about 5.5 mm. Even allowing for a factor of 3 or a little more for the extent of the compression, *Pharyngolepis oblongus* can not have been as rounded in cross section as KIAER believed but must, on the contrary, have been a laterally compressed, deep-bodied form with a depth of about twice its thickness. This conclusion seems to be amply confirmed by similar measurements on other specimens.

Measurements on the head of E. 1068 are rather difficult because of the small part that is preserved, but the width across the orbito-temporal division seems to be about 14.5 mm; the length of the head is perhaps about 21.5 mm.

The importance of this specimen lies in the fact that, whilst it can be identified as a specimen of *Pharyngolepis oblongus*, much of the lateral and ventral parts of the head and immediately post-cranial scales are present.

Remarks. In KIAER's reconstruction of *Pharyngolepis oblongus* (KIAER 1924, Fig. 37, p. 81) it will be noticed that the squamation of the cheek and ventral visceral exoskeleton does not agree with that described above. We must, I think, believe that KIAER used the specimen of *Pharyngolepis kiaeri* (E. 1116 + E. 1043) for parts of his reconstruction, this would account for the discrepancies. A number of characters are involved including the size and shape of plate *G*, in *Pharyngolepis oblongus*, unlike *Pharyngolepis kiaeri*, there are several smaller plates comprising the *G* series.

PHARYNGOLEPIS KIAERI sp. nov. (Text Figures 2, 3 B, 4 B, and 8; Plates IV A, IV B, V 1).

Diagnosis: — orbital openings situated on the mid-transverse line of the cranial roof; the pineal foramen lies between the mid-parts of the orbital openings but posterior to the midtransverse line of the cranial roof; the nasal part of the nasohypophysial foramen lies just between the orbits anterior to the mid-transverse line of the cranial roof; the hypophysial part of the nasohypophysial foramen opens just anterior to a line drawn through the anterior margins of the orbits. The posterior boundary of the cranial roof is rather well defined with an acute posterior angle; the small, irregularly rhomboidal scales in the occipital division of the cranial roof less numerous than in *Pharyngolepis oblongus*. Plates bordering the groove pl_a between the otic and occipital divisions of the cranial roof

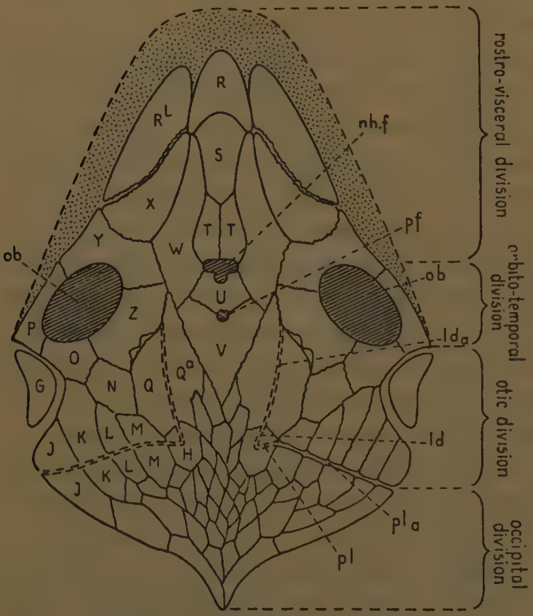

Fig. 2. Pharyngolepis kiaeri sp.nov., dermal cranial roof of Specimen E. 1043 (Pal. Mus. Oslo) flattened in the horizontal plane and seen in basal (internal) view. Drawing based on specimens E. 1116 and E. 1043 (Pal. Mus. Oslo). Lettering as in Text Fig. 1. (see also Plate IV A and B). X 2.8.

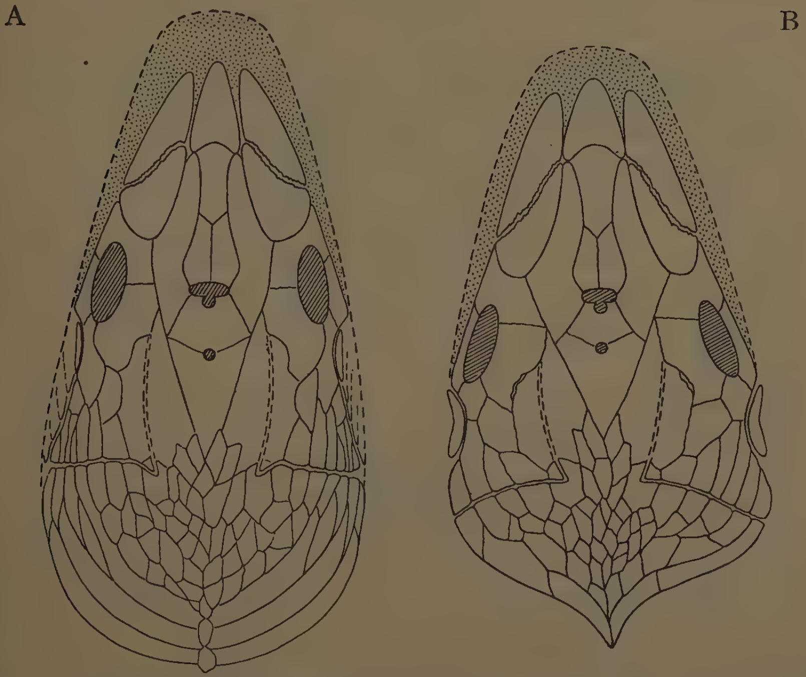

Fig. 3. Pharyngolepis, attempted restorations of the cranial roof in dorsal aspect drawn from wax-plate models. A, *Pharyngolepis oblongus* KIAER, X 2.7; B, *Pharyngolepis kiaeri* sp.nov., X 2.8.

are rather few (not more than 6 in the holotype). The lateral post-orbital emargination in the otic division is largely filled by a single, rather large plate, *G*. The latero-ventral scales of the cheek and ventral visceral exoskeleton are small, rather uniform in size, lozenge-shaped and very numerous. There is, incidentally, neither in this species nor in *Pharyngolepis oblongus* a sharp demarkation between the cheek and ventral visceral scales (referred to in this paper as scale fields *c* and *d* respectively).

The following characters are also typical of this species: measured on the flattened head, the greatest width of the cranial roof is across plates *P* – *P* in the orbito-temporal division. The rostral part of the rostro-visceral division is narrow and broadens out almost uniformly to plates *P* – *P* at an angle of 60°. Plate *U* is small, not meeting

Q^a laterally; plate *V* has truncated anterior angles. The apex of the V-shaped groove on plate *H* lies at less than one third of the length from the posterior to the anterior end of the cranial roof – or, if the posterior angle of the cranial roof is rounded off, at less than one quarter of the length. The length to breadth ratio of the plate complex *R, S, T, U, V, W* is about 2½ : 1, that of plate *R* is about 1¼ : 1, of plate R^L about 3½ : 1, and of plate *X* about 2¼ : 1.

Holotype: — one nearly complete specimen with the counterpart of the head and anterior part of the trunk; Specimens E. 1116 and E. 1043 (Pal. Mus. Oslo). E. 1116 is figured by KIAER (1924) in Plate X, Fig. 1.

Material: — the only material referable to the species consists of the holotype and its counterpart.

Description. The specimen, which is fairly complete, passes through the rock matrix from one side to the other with the greater part of the ventral surface hidden and the distal parts of the tail are missing; in this specimen a short section of vertebral column has been observed with the aid of an X-ray examination (SMITH 1956). The head and trunk regions are preserved on one side of the matrix in an almost dorso-ventral position, a considerable part of the squamation of the cheek and ventral visceral exoskeleton is present on the right side but otherwise only the dorsal surface is visible. On the reverse side of the matrix the posterior part of the trunk and the proximal part of the tail are laterally flattened with the right side exposed. The total length of the specimen is approximately 135 mm, the length of the anterior piece is 92 mm. The length of the cranial roof is 28 mm and its maximum width, which cannot be determined exactly, seems to be about 20.5 m. The distance from the tip of plate *R* to the anterior margin of the orbit is 12 mm, that from the tip of plate *R* to the pineal foramen is 12.5 mm, and to the angle of the V-shaped groove on plate *H* is 19.5 mm.

Remarks. KIAER referred this specimen to the species *Pharyngolepis oblongus* which it closely resembles in many respects and, indeed, no differences have been detected other than in the cranial roof and adjacent areas of exoskeleton where, however, there are several characters, mostly those of relative proportions, in which it differs quite consider-

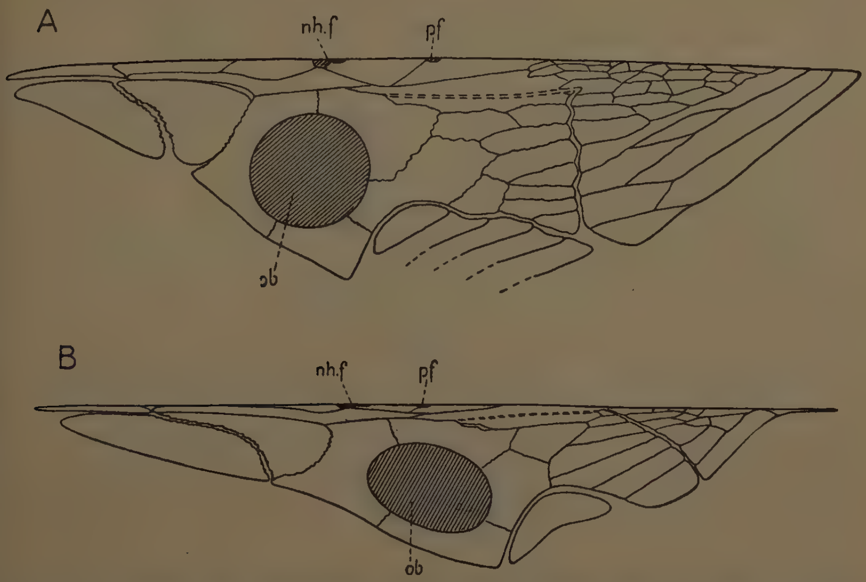

Fig. 4. Pharyngolepis, attempted restorations of the cranial roof from the side using same models as in Text Fig. 3. A, *Pharyngolepis oblongus* KIAER, X 4.5; B. *Pharyngolepis kiaeri* sp. nov., X 3.75.
ob = *orbit; nh.f* = nasohypophysial foramen; *pf* = pineal foramen.

ably from *Pharyngolepis oblongus* and which do not seem to be result of the state of preservation. The possibility that we are here concerned with sexual dimorphism can certainly not be ignored but, in the absence of any positive indications, can probably be discounted. Nor is there any evidence of continuous variation within *Pharyngolepis oblongus* and, in the circumstances, it seems most likely that E. 1116 and E. 1043 truely represent a new species. KIAER mentioned the possibility of a second species of *Pharyngolepis* with reference to a small specimen having only 12 branchial openings instead of the usual 15 (KIAER 1924, pp. 61 and 134). I have had the opportunity to examine this specimen (now E. 1036, Pal. Mus. Oslo) but there are no means by which to associate it with one species or the other, or to errect for it a new species; it may be a variation of one or other of the species described or a juvenile form and for the present it must remain included in the species *Pharyngolepis oblongus*.

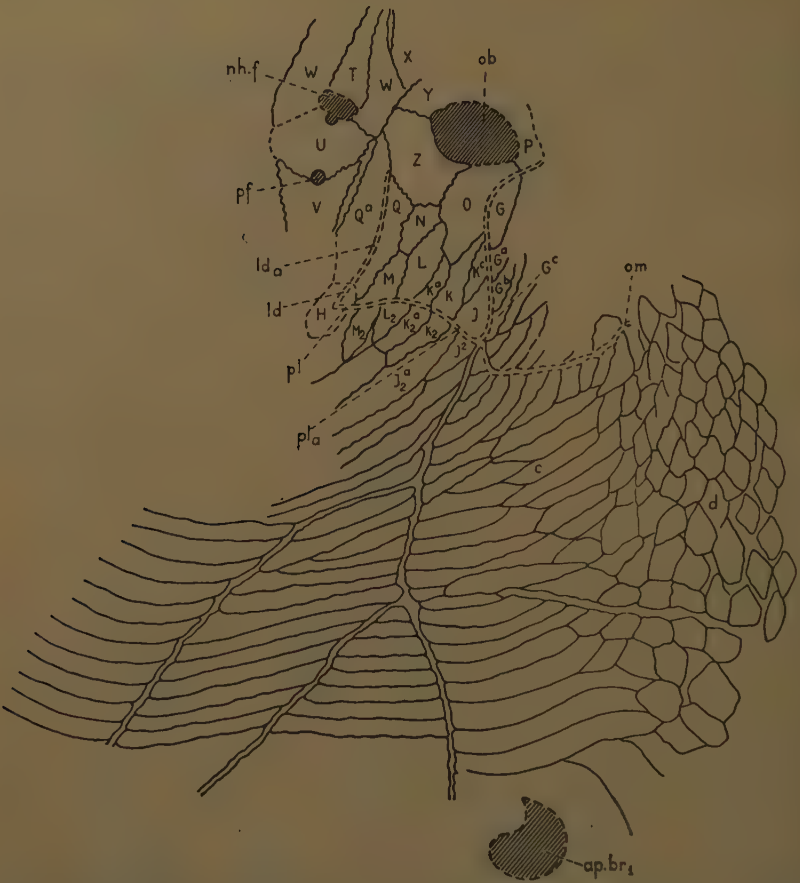

Fig. 5. Pharyngolepis oblongus KIAER, part of the cranial roof and adjacent areas of exoskeleton of Specimen E. 1068 (Pal. Mus. Oslo). X 3.6. *c* = cheek exoskeleton; *d* = ventral visceral exoskeleton; $ap.br_1$ = first branchial opening; *ld* and ld_a = cranial part of the dorsal lateral-line groove; *nh.f* = nasohypophysial foramen; *ob* = orbit; *om* = sensory-line groove on cheek exoskeleton; *pf* = pineal foramen. Note the large, rhomboidal scales in scale-field *d* increasing in size ventrally. (see also Plate III).

On the basis of all the characters described, the three specimens referred to the species *Pharyngolepis oblongus* fall into a compact group with no overlapping of characters of *Pharyngolepis kiaeri*. On the other hand, the number, arrangement, and general shape of the head plates is fundamentally the same in the two species as can be seen from Text Figures 1 and 2, except in the case of the scales on the occipital division of the cranial roof, the plates bordering the groove pl_a and, as already emphasized, the scales of the cheek and ventral visceral exoskeleton. The position of the orbits, pineal and nasohypohysial foramina and the position of the greatest width of the cranial roof, together with the rostral angle and the relative proportions of certain parts of the cranial roof provide the major differences.

Discussion

The dermal elements of the skull roof, cheek and supra-trematic parts of the branchial region of an armoured Anaspid are basically comparable with the exoskeleton of the cephalic shield of a Cephalaspid in general features although the exoskeleton of the cephalic shield is frequently more extensive caudally (e. g. *Thyestes*, *Dartmuthia*, *Tremataspis*). The orbital openings and nasohypophysial and pineal foramina in both groups lie in corresponding positions and the part of the cranial roof anterior to the nasal opening in Anaspids is, as in Cephalaspids, of visceral origin but covered by dermal plates which include the so-called «rostral» plates — i. e. those situated on the rostral part of the visceral endoskeleton, morphologically sub-ethmoidal (Stensiö 1927, 1939, 1957). The nasohypophysial and pineal foramina pierce the median (ethmoidal) part of the orbito-temporal division of the cranial roof. The dorsal and lateral sides of the exoskeleton of the adult Cephalaspid shield form a continuous piece of bone (Stensiö 1957, p. 188) whilst the corresponding exoskeletal parts in Anaspids are composed of a considerable number of small, rhomboidal scales and larger plates. The mouth in both groups is sub-terminal and the ventral visceral exoskeleton in Anaspids (*Rhyncholepis* is a notable exception) resembles that of Cephalaspids rather closely in being made up of a large number of small dermal elements which, like the exoskeleton of the cheek and pre-branchial regions also of Anaspids, was undoubtedly a flexible area. The nature of the ventral visceral squamation in Cephalaspids indicates that the internal structures — cartilages and muscles — were adapted for producing a flow of water through the pharyngeal region and over the gills; the

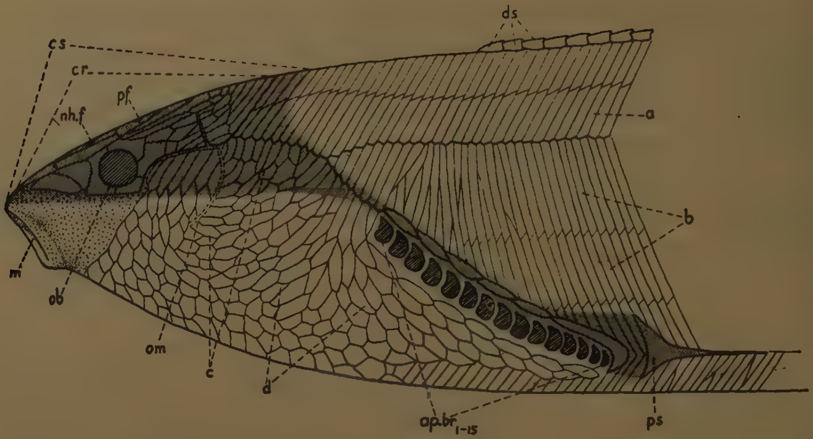

Fig. 6. Pharyngolepis oblongus KIAER, an attempted new reconstruction of the head and anterior end of the body in lateral view: modified after KIAER 1924, Text Fig. 37; and STENSIÖ 1957, Text Fig. 127A. The area *cs* (shaded) indicates the approximate extent of the exoskeleton which corresponds to the cephalic shield of a Cephalaspid and includes the cranial roof (*cr*), the pectorial spine (ventro-lateral scute) apparatus (*ps*), and the strip of exoskeleton above the branchial openings ($ap.br_{1-15}$). The stippled area indicates soft tissues free from exoskeleton which extend forwards to form the actual mouth. Other lettering : *c* = cheek exoskeleton; *d* = ventral visceral exoskeleton; *ds* = dorsal ridge scales; *nh.f* = nasohypophysial foramen; *m* = oral opening; *ob* = orbit; *om* = sensory-line groove on the cheek exoskeleton; *pf* = pineal foramen. X 1.6.

combined areas of flexible squamation in Anaspids overlay regions which had both this function and that of accommodating, like the corresponding regions in modern Petromyzontids (in which, however, the exoskeleton is absent), sucking mouth-parts and a rasping tongue (STENSIÖ 1957, p. 227). It is interesting to note in this connection that amongst the Cephalaspids, the primitive *Aceraspidae* also possessed a rasping tongue mechanism (STENSIÖ 1957; see also the footnote on p. 379).

In Text Figure 6 an attempt has been made to indicate the areas of exoskeleton in an Anaspid (*Pharyngolepis oblongus*) which correspond to the cephalic shield and ventral visceral exoskeleton of Cephalaspids. Apart from the lesser breadth of the heads and the more numerous dermal elements in the Anaspids, the most obvious difference is in the position of the branchial openings. STENSIÖ (1957) has already shown that by reference to a form such as *Trematapsis* in which the cephalic shield is oval in cross section and is produced back as far as the anal opening, and that by assuming the loss in Anaspids of several (three) anterior gill-pouches together with a small backward shift of the remainder, a correlation can be made. The thickened bony flanges external to the eyes and dorso-lateral to the branchial openings in the majority of Cephalaspids are clearly secondary formations.

It is most probable that in Cephalaspids, whilst the usual number of branchial openings is ten with a reduced eleventh, a much larger number was primitively present and that they extended further back on the ventral side of the pharyngeal region but have been eliminated by the development of the post-brancial wall of the cephalic shield. The evolution of a cephalic shield and the fusion of the lateral halves of the visceral endoskeleton in the median line to form a post-branchial wall imposed a limit on the branchial region in Cephalaspids. Additional branchial openings developed, however, during ontogeny in some Anaspids and, if STENSIÖ is correct in believing that the first three, pro-otic, gills of the Cephalaspid series (pre-spiracular, spiracular and hyoidean) have disappeared from Anaspids, then the persisting 6–8 branchial openings in *Lasanius* and 8 in *Birkenia* should be the same as the openings of the branchial chambers k_4–k_{11} in Cephalaspids (see e. g. STENSIÖ 1957, Text Fig. 116). But *Pharyngolepis* for example, with its usual total of 15 branchial openings, must have retained eight additional, primitive, vagal-innervated gills, thus resembling the Heterostraci and Myxinoids. In adult Myxinoids the region of branchial openings frequently extends far back along the flanks and there is never a limiting post-branchial wall. In larval Myzinoids, e. g. *Bdellostoma* (see DEAN 1899; STENSIÖ 1927, 1957) the branchial region is short and the primordia of the developing visceral endoskeleton diverge backwards on either side of the head and have the potentiality for unlimited backward growth. The larval head of Myxinoids is considerably flattened dorso-ventrally and, in many respects, resembles a Pteraspid such as *Simopteraspis primaeva* KIAER (Text Fig. 7) to a striking degree. In *Simopteraspis*, as in Pteraspids

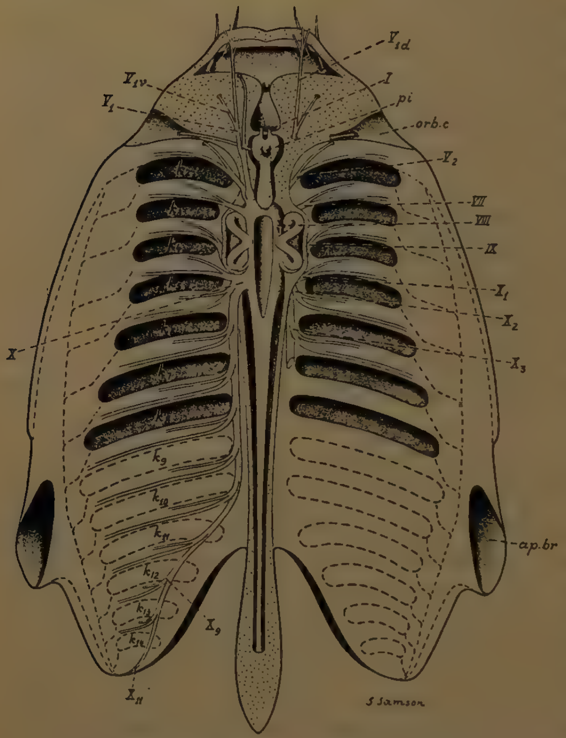

Fig. 7. Simopteraspis primaeva (Kiaer), an attempted reconstruction of the endocranium to show the number and arrangement of the branchial chambers. A limiting post-branchial wall is absent. After Stensiö 1957, Text Figure 200. X 3.3. *ap.br.* = branchial apperture; $k_2 - k_{14}$ = branchial chambers; V_1 = profundus nerve; V_{1d}, V_{1v} = dorsal and ventral branches respectively of the profundus nerve; V_2 = trigeminal nerve; *VII* = facialis nerve; *VIII* = auditory nerve; *IX* = glossopharyngeus nerve; $X_1 - X_{11}$ = branchiomeric branches of the vagus nerve; *orb.c* = orbital cavity; *pi* = pineal organ.

in general, there may have been up to 15 branchial chambers with no union between the posterior parts of the visceral endoskeleton of both sides, i. e. no post-branchial wall. The Anaspids with branchial openings ranging from as few as 6 (in *Lasanius*) to as many as 15 (in *Pharyngolepis*) clearly resembled the Heterostraci and Myxinoids in having no posterior limit to the branchial region, and Stensiö's idea of a post-branchial wall in *Pterygolepis* (Stensiö 1957, Fig. 127B) must be incorrect; we should rather expect an arrangement of gills more nearly resembling that in the Heterostraci in which the two halves of the visceral endoskeleton remain indipendant posteriorly and separate medially. The pericardial cartilage of Petromyzontids is the homologue of the post-branchial wall in Cephalaspids; in both these groups the two halves of the posterior visceral endoskeleton have come together and joined so that the branchial openings are limited posteriorly and fixed in number — ten plus a reduced eleventh in Cephalaspids; seven, with the three anterior ones absent in Petromyzontids.

KIAER was unable to decide the location of the otic capsules in any of the Norwegian Anaspids and the matter still remains in doubt although in *Pharyngolepis* they must have underlain approximately plates *Q*, Q^a, *L*, *M*, *N*, *O*. In one specimen of *Pterygolepis* a pair a lateral depressions are present posterior to the orbital openings on the cranial roof and may be due to the dermal elements having been crushed down on the otic capsules; and in *Lasanius* the capsules themselves, which had a perichondral ossification and were not covered by thick dermal plates, have been identified with even some indication of the actual form of the labyrinth in several specimens. Full descriptions of these two cases will be given on other occasions.

The dermal plates and scales of the cranial roof of *Pharyngolepis* are ornamented with small bony tubercles which are irregularly spaced but which on the larger plates are arranged in rows radiating from the centres of ossification; in the smaller plates and scales such a distribution can generally not be made out. A «mucous-canal» system (see STENSIÖ 1957, pp. 266–267[1]) is slightly developed on some of the cranial plates e.g. on plates *T*, *W* etc. but it is too inconsiderable compared with that in e.g. *Pterygolepis* for a description to have any value. On the trunk scales the tubercles are arranged in irregularly spaced rostro-caudal rows, obliquely transverse to the vertical axis of the scales; a similar pattern is to be seen on the trunk scales of *Pterygolepis* and also in *Rhyncholepis* but in the latter genus the rows are more pronounced because of the very much smaller size of the tubercles, and the closer spacing of the rows. An appearance suggesting parallel fibres is the result. The same pattern of tubercles is not generally obvious in *Birkenia* since the tubercles are more randomly scattered on the scales; the arrangement of the tubercles on the trunk scales of some specimens of *Pterygolepis* is a little reminiscent of that in *Birkenia* (see Plate V 1 – 4). As Stensiö (1957) has pointed out, the scale with fine rows of tubercles and strong basal ridges was probably present in *Jamoytius kerwoodi* White (1946) and the markings interpreted by White as muscle-fibres are, in fact, more likely to be the remains of tubercle rows; the structures which White called myocommata are the thickened, basal, dorso-ventral ridges of the scales. This view is much more in keeping with the state of preservation of *Jamoytius* than the belief that traces of soft tissues have survived in a recognizable form. Reference to an approximately contemporary form, *Lasanius*, from almost the same locality (Logan Water, Lanarkshire), without any consideration of the taxonomic status of *Jamoytius*, reinforces this opinion. For the mostpart, the exoskeleton of *Lasanius* was in a still greater state of reduction and only the merest traces of the basal, dorso-ventral ridges of the scales can be seen in a few, favoured specimens, rows of tubercles are not seen. Of non-calcified internal structures there remain in *Lasanius* only slight traces of a vertebral column and, in one or two examples, what has been taken to be intestine, stained doubtless by its bituminous contents. For the rest, where they remain, the soft tissues form a thin, undifferentiated, carbonized film on the matrix.

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[1] STENSIÖ (loc. cit.) and STENSIÖ & ØRVIG (unpublished) point out that the system of grooves or canals present on the dermal exoskeleton of Ostracoderms was quite clearly not a mucous canal system. The grooves surround, in fact, the individual scale elements which have fused to form larger plates or shields, the bottoms of the grooves lie lower than the depth of the dentinous layer and communicate with the channels and cavities of the basal layer of the exoskeleton. Thus the grooves could contain nerve-endings and blood-vessels which could not penetrate the dentinous layer, and from these grooves the epidermis could regenerate over the compact surface of the exoskeleon. In Anaspida, the outer, compact layers have been lost from the exoskeleon and the grooves are consequently shallow, but still visible though no longer essential since nerves and blood-vessels were able to penetrate all parts of the exoskeleton (Plate VI).

A final point of interest connected with the exoskeleton concerns Stensiö's suggestion (Stensiö 1939) that the dermal cranial roof in Anaspids may not have consisted of fully indipendant plates. In *Pharyngolepis* the sutures between the plates and scales do, as far as one can judge from imperfect specimens, pass right through the hard tissues but it is possible that some of the grooves on the head e. g. that between plates Q and Q^a may originally not have been so deep (in the fossils the matrix is frequently seen in the grooves between plates Q and Q_a but this could be the result of a fracture along the line of the groove). In this respect *Pharyngolepis* does seem to differ in some degree from *Pterygolepis* (and probably from *Rhyncholepis*

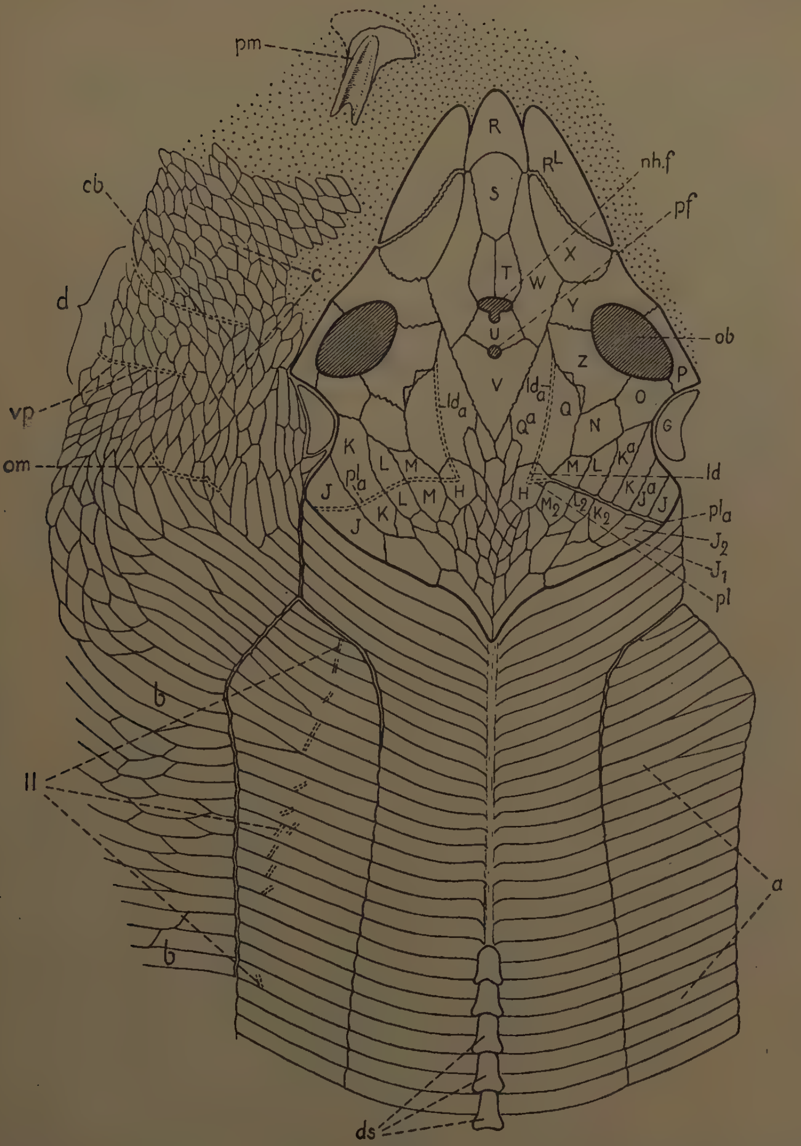

Fig. 8. Pharyngolepis kiaeri sp.nov., exoskeleton of the head and anterior trunk regions with parts of the squamation of the cheek (*c*) and ventral visceral exoskeleton (*d*) on the left side. Drawn from specimens E. 1116 and E. 1043 (Pal. Mus. Oslo), flattened in the horizontal plane and seen in basal (internal)

also) but none of the specimens is complete enough for a definite conclusion to be reached. The matter is, however, of some importance in assessing the extent of the homology between Anaspid and Cephalaspid cranial roofs.

Note on the Sensory-line System of *Pharyngolepis*

The exoskeleton in Anaspids is represented by only a single, rather thick isopedine layer which was situated in the *stratum compactum* of the corium. The outer layers of the corium were without hard tissue of any kind. Consequently the exoskeleton of Anaspids corresponds to the basal layer only of the exoskeleton in Cephalaspids and Heterostraci, (see further GROSS 1938; STENSIÖ 1939; and the footnote on p. 393 of this paper). The sensory-lines of Anaspids, which the evidence suggests were probably always pit-lines, lay rather superficially in the epidermis and outer parts of the corium and could not, therefore, as a rule cause any grooves to form on the exoskeleton. Exceptions to this rule are, however, found in *Pharyngolepis* where in certain areas the sensory-lines have apparently left markings on the exoskeleton (see Text Figures 8 and 10), this has most likely occurred in places where the corium was particularly thin. These markings are as follows (see Text Figure 8) : firstly, two pit-line grooves meeting at an angle on plate *H*, a longitudinal pit-line groove (*ld*) and a transverse one (*pl*). Associated with these grooves are two more, very consistent, grooves one of which (ld_a) lies between plates Q and Q^a and seems to form an anterior continuation of *ld* the other (pl_a) is a transverse groove, sometimes deep, sometimes shallow, which runs from *pl* to the lateral margin of the cranial roof between the otic and the occipital divisions of the cranial roof. The groove pl_a may cross the centres of ossification of plates *J*, *K*, *L*, *M* (as shown on the left side of Text Figure 8) or it may pass more deeply between fully indipen-

view. X 2.8. *a*, *b* = dorso-lateral and lateral scale-fields respectively; *ds* = dorsal ridge scales; *ld* and ld_a = cranial part of dorsal-lateral-line groove; *ll* = pit-line groove belonging to the main lateral-line; *om*, *cb*, *vp* = sensory-line grooves on the cheek and ventral visceral exoskeleton; *pl* and pl_a = grooves corresponding to the posterior pit-line of fishes; *pm* = mandibular plate (see further STENSIÖ 1957, p. 227). For lettering of the cranial roof plates see also Text Figure 2.

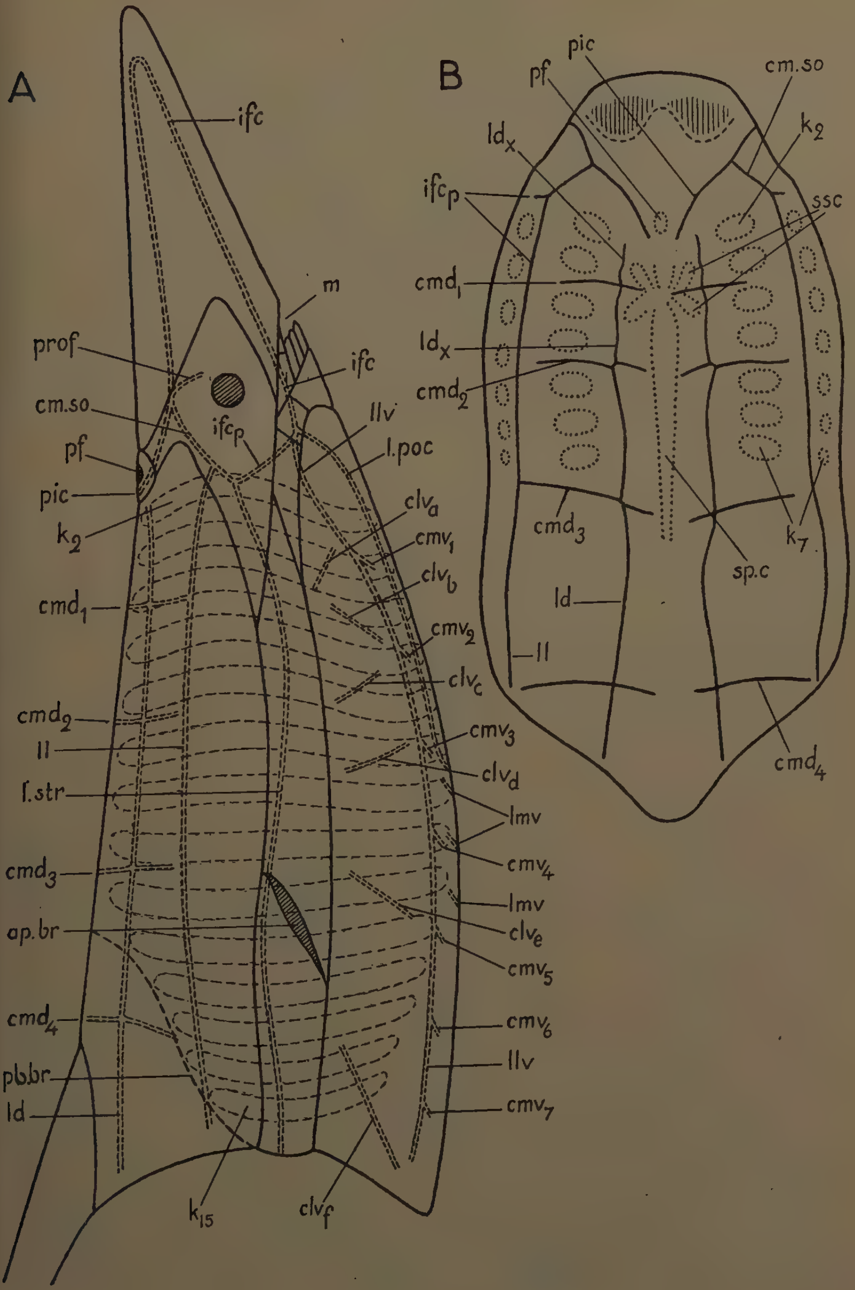

Fig. 9. The text next page.

dant plates *J*, J^a, *K*, K^a etc. (as shown on the right side of Text Figure 8). The grooves *ld* and ld_a of *Pharyngolepis* may be compared with the canal ld_x, the anterior part of the dorsal lateral-line canal, in a Heterostracan such as *Poraspis polaris* (Text Figure 9 B), and they are found to correspond closely in position; *ld* and ld_a may thus be identified with reasonable certainty as part of the dorsal lateral-line system lying on the cranial roof. The transverse grooves *pl* and pl_a are also seen to have a morphological position closely similar to cmd_2 in *Poraspis polaris*, both running transversely across the cranial roof posterior to the ear (see p. 393). Consequently, *pl* and pl_a are most probably homologous with the so-called «supra-temporal commissure» of *Petromyzon* and with the posterior pit-line of fishes in general (see *inter alia* Allis 1889; Jarvik 1948; Johnston 1905; Stensiö 1957).

Secondly, in the specimen of *Pharyngolepis kiaeri* (Text Figures 8 and 10) behind the cranial roof in the scale-field *a* is an irregular series of short, shallow pit-line grooves (*ll*). These pit-line grooves lie more or less transversely across the scales but in a few instances they appear to lie across the hiatus between two scales. It is quite clear from the position and alignment of this series of pit-line grooves

Fig. 9. The sensory-line system in Heterostraci. A, diagram of a generalized pteraspidomorph heterostracan in which a compilation of all the known sensory-line canals and pit-line grooves in Heterostraci, taken from various sources, has been laid in, and is seen in lateral view. Outline of the diagram based on White's restoration of *Pteraspis rostrata* v. *toombsi* White 1935. B, *Poraspis polaris* Kiaer, dorsal disc of the carapace to show sensory-line canal system. After Kiaer 1932; lettering after Stensiö 1957. *ap.br* = branchial apperture; clv_{a-f} = hypotrematic transverse commissural sensory-lines; cmd_{1-4} = dorsal post-orbital transverse sensory-line commissures; cmd_2 = sensory-line canal corresponding to the posterior pit-line of fishes in general; cmv_{1-6} = ventral post-oral transverse sensory-line commissures; *cm.so* = supra-orbital transverse sensory-line commissure; *ifc*, ifc_p = infra-orbital sensory-line canal; k_2 — k_{15} = branchial chambers; *ld* = dorsal lateral-line canal; ld_x = cranial part of dorsal lateral-line canal, *ll* = main lateral-line canal; *llv* = ventral longitudinal sensory-line canal; *lmv* = median ventral sensory-line canal; *l.poc* = post-oral ventral sensory-line canal; *l.str* = supra-trematic sensory-line canal; *m* = oral opening; *pb.br* = probable posterior limit of visceral endoskeleton; *pf* = pineal foramen; *pic* = pineal sensory-line canal; *prof* = «profundus» sensory-line canal; *soc* = supra-orbital sensory-line canal; *sp.c* = spinal cord; *ss.c* = semicircular canals.

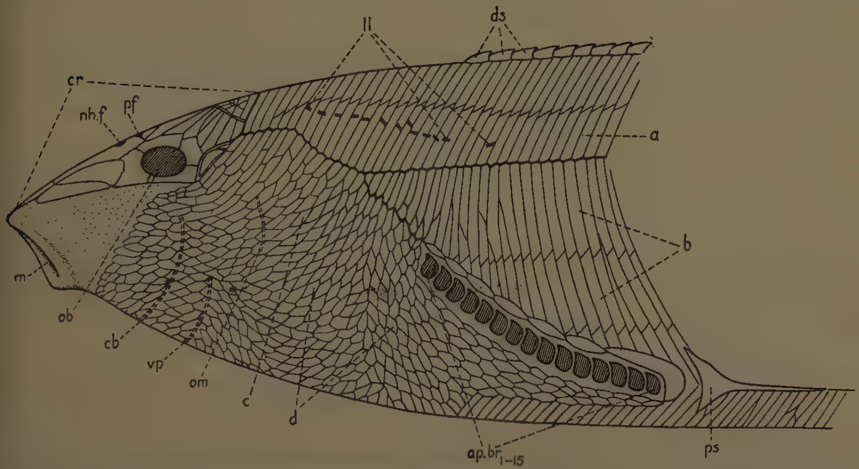

Fig. 10. Pharyngolepis kiaeri sp.nov., an attempted reconstruction in latera view of the head and anterior end of the body and the sensory-line system. X 2. *a* = dorso-lateral scale-field; $ap.br_{1-15}$ = branchial appertures; *b* = lateral scale-field; *c* = cheek exoskeleton; *cr* = cranial roof; *d* = ventral visceral exoskeleton; ds_1 = first dorsal ridge scale; *ll* = pit-line grooves corresponding to part of the main lateral-line; *m* = oral opening; *nh.f* = nasohypophysial foramen; *ob* = orbit; *om, vp, cb* = sensory-line grooves on cheek and ventral visceral exoskeleton; *pf* = pineal foramen; *ps* = pectoral (ventro-lateral scute) apparatus. The stippled area indicates the region of soft tissues around the mouth.

that they belong to the main lateral-line, and are homologous with part of *ll* in *Poraspis polaris* and other Heterostraci (Text Figure 9). Although not marked on the exoskeleton, the main lateral-line of *Pharyngolepis* probably continued back on the scale-field *b* (see Text Figure 10) towards the tail. The pit-line grooves (*ll*) were observed, but not identified by Kiaer (1924) and can be seen in his Figure 37, p. 81.

Running almost vertically downwards on the ventral visceral exoskeleton and partly on the cheek (scale-fields *c* and *d* in Text Figure 10) in the specimen of *Pharyngolepis kiaeri* there are three rather faint grooves which have most probably been caused by sensory-lines; in succession from the posterior they are *om*, *vp*, and *cb*. The groove *om* is a most directly ventral to the end of pl_a and a corresponding groove seems to have been present in *Pharyngolepis oblongus* (Text Figures 5 and 6, *om*), *vp* lies at about the level of

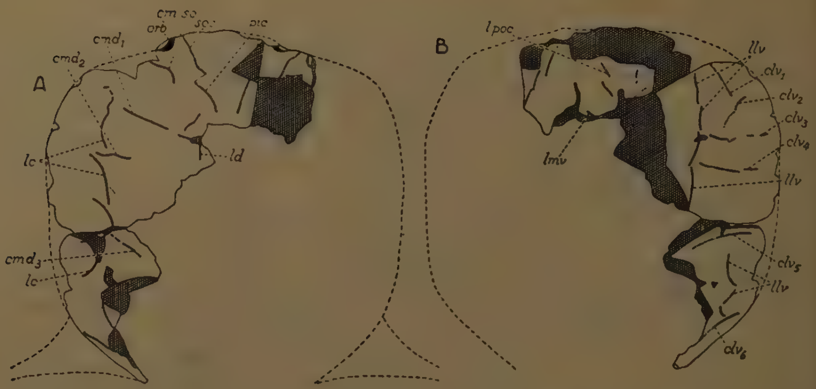

Fig. 11. Amphiaspis argos OBRUTSCHEV; showing the sensory-line grooves of the carapace in dorsal (A) and ventral (B) views. From OBRUTSCHEV 1939, after STENSIÖ 1957. X approximately $^1/_6$. $clv_{1\text{-}6}$ = hypotrematic transverse commissural sensory-lines; $cmd_{1\text{-}3}$ = dorsal, post-orbital, transverse sensory-line commissures; cmd_2 = sensory-line groove corresponding to the posterior pit-line of vertebrates in general; *cm.so* = supra-orbital transverse sensory-line commissure; *lc* = main lateral-line groove; *ld* = dorsal lateral-line groove; *llv, lmv* = lateral and medial ventral sensory-line grooves respectively; *l.poc* = post-oral sensory-line groove; *orb* = orbit; *pic* = pineal sensory-line groove; *soc* = supra-orbital sensory-line groove.

the anterior end of the plate *G*, and the groove *cb* is approximately level with the posterior margin of the orbit. Each of these grooves crosses fields of small, rhomboidal scales and it is difficult to make certain of their exact relationships to the scales, but in some cases (even in the same groove) they appear to cross centres of ossification whilst elsewhere they run between individual scales. In the more typical Heterostraci there are no sensory-lines corresponding in position to the grooves *om*, *vp*, and *cb* but in a peculiar and little-known form, *Amphiaspis argos* OBRUTSCHEV (1939) there is a series of six short, rather irregularly arranged sensory-line grooves situated ventro-laterally (see Text Figure 11). This series has been denoted by STENSIÖ (1957) as clv_a — clv_f. Without entering into a detailed discussion on this *clv* series in the present paper, it may be mentioned that the grooves *om*, *vp* and *cb* in *Pharyngolepis* appear to represent three members of the *clv* series in *Amphiaspis*.

In view of the relationships of the grooves *om*, *vp* and *cb* and especially of ld_a and pl_a to the dermal elements, it is not inconceivable that some of the other sutures and hiatuses between plates and scales in *Pharyngolepis* also housed sensory-lines.

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PLATES I–VI

(None of the plates are retouched).

PLATE I.

Pharyngolepis oblongus KIAER; counterpart of the lectotype. Most of the cranial roof and anterior dorsal trunk squamation is seen in basal (internal) view. Same specimen as in Text Figure 1A. The tubercles on the surface of the plates and scales are visible but most of the underlying bone is missing. Downtonian, Ringerike, Norway. Specimen E. 0122 (Pal. Mus. Oslo). X 3.2. Photographed in xylol. ds_1 = first dorsal ridge scales; ld_a = cranial part of the dorsal lateral-line groove; *nh.f* = nasohypophysial foramen; *ob* = orbit; *os* = scales of the occipital division of the cranial roof; *pf* = pineal foramen; pl_a = posterior pit-line groove.

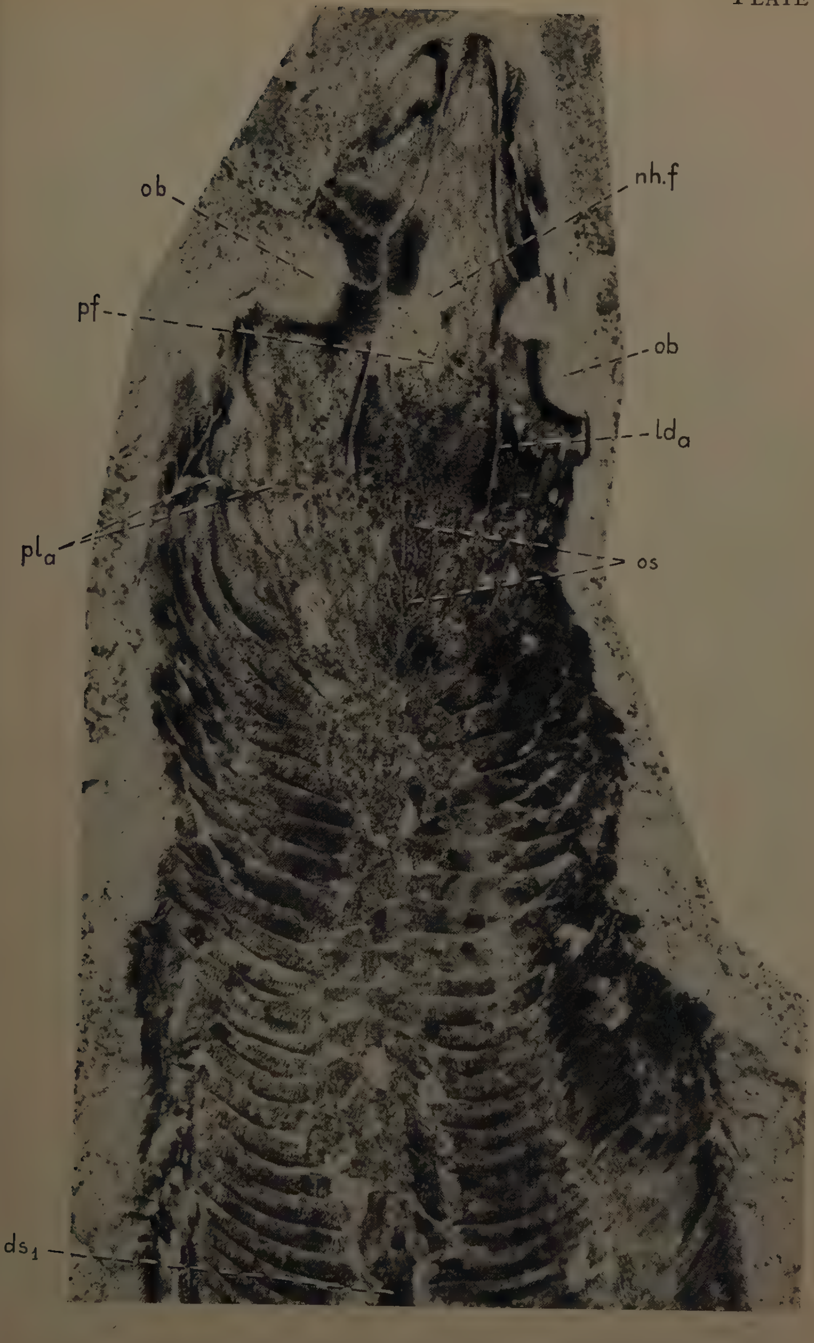

ob
nh.f
pf
ob
ld_a
pl_a
os
ds_1

PLATE II.

Pharyngolepis oblongus KIAER; part of cranial roof and ventral visceral exoskeleton of the left side in basal (internal) view of Specimen E. 1039 (Pal. Mus. Oslo), Downtonian, Ringerike, Norway. Same specimen as in Text Figure 1B. Much of the bone substance is missing but the surface tubercles are visible. X 4.5. Photographed in 95 % alcohol. *d* = ventral visceral exoskeleton; *H* = small hexagonal plate carrying pit-line grooves; ld, ld_a = cranial part of dorsal lateral-line groove; pl, pl_a = posterior pit-line groove; other lettering as in Plate I.

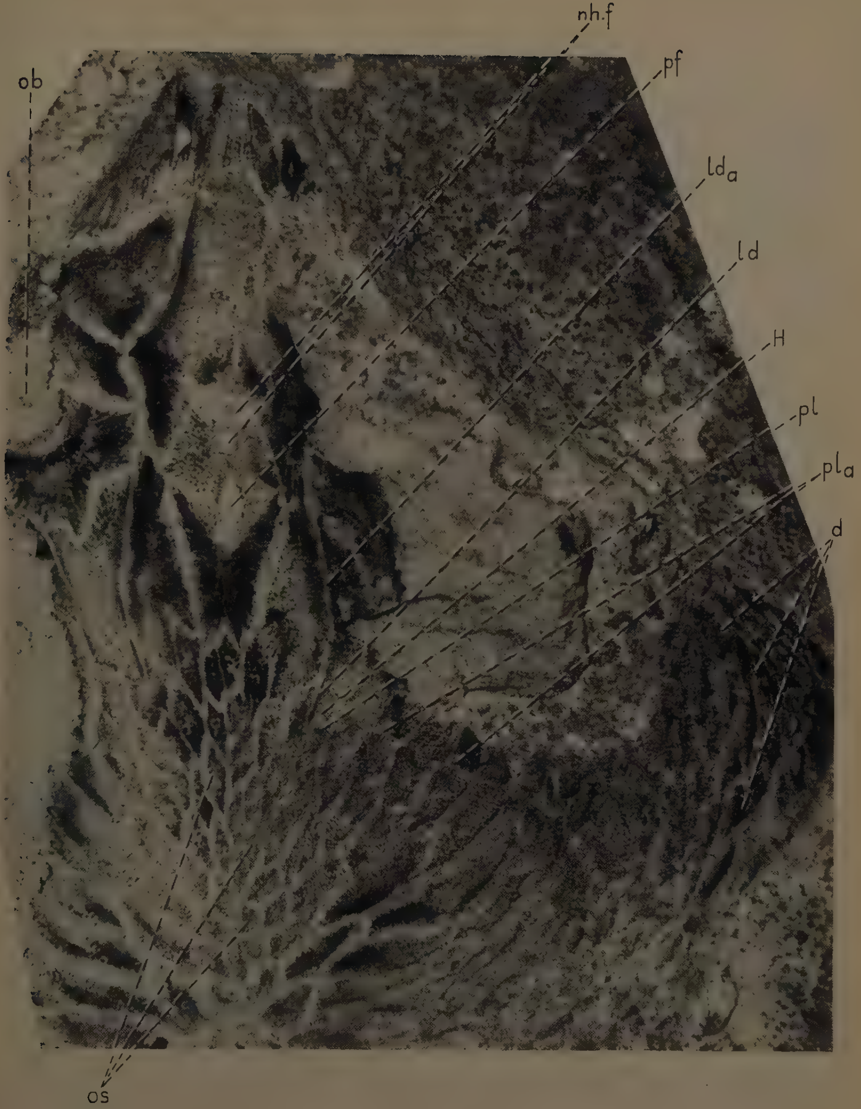

nh.f
pf
ob
ld_a
ld
H
pl
pl_a
d
os

PLATE III.

Pharyngolepis oblongus KIAER; mid-median and left side of cranial roof of Specimen E. 1068 (Pal. Mus. Oslo) with adjacent areas of scales including most of the cheek and ventral visceral exoskeleton in basal (internal) view. In general only the superficial tubercles have retained bone substance. Same specimen as in Text Figure 5. Downtonian, Ringerike, Norway. X 3.3. Photographed in xylol. *a*, *b* = dorso-lateral and lateral scale-fields respectively; *c*, *d* = cheek and ventral visceral exoskeleton respectively; $ap.br_1$ = first branchial opening; *om* = sensory-line groove on cheek and ventral visceral exoskeleton; other lettering as in Plate I.

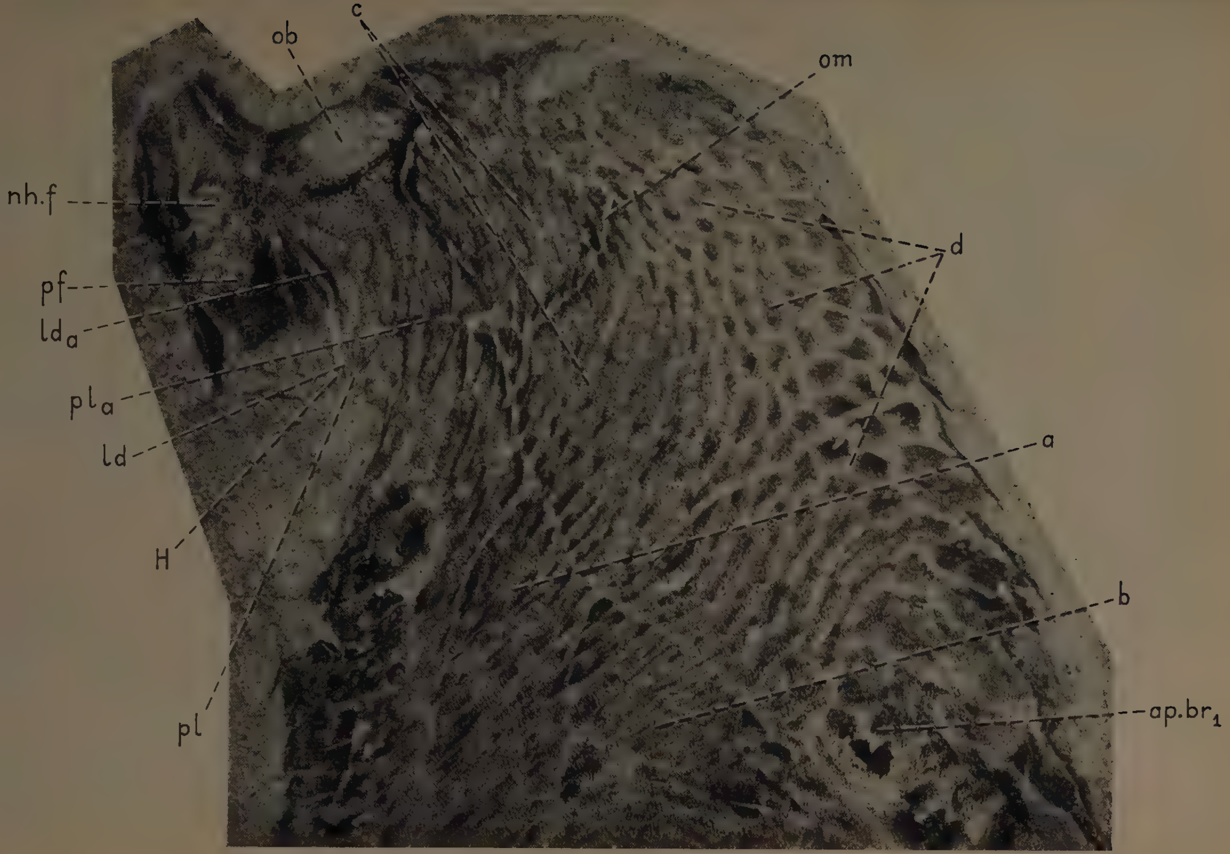

c
ob
om
nh.f
d
pf
ld$_a$
pl$_a$
ld
a
H
b
pl
ap.br$_1$

PLATE IV A.

Figure 1. Pharyngolepis kiaeri sp. nov., holotype. Cranial roof and part of the cheek and ventral visceral exoskeleton of the right side and anterior dorsal trunk squamation of Specimen E. 1043 (Pal. Mus. Oslo) seen in basal (internal) view. Same specimen as in Text Figure 8. Downtonian, Ringerike, Norway. X 3.3. Photographed in 95 % alcohol.

Figure 2. Part of a latex impression of the same specimen to show some details in the region of the orbit. X 3.3. Photographed dry and lightly smoked with ammonium chloride. *om, vp, cb* = sensory-line grooves on the cheek (*c*) and ventral visceral (*d*) exoskeleton; *ll* = pit-line grooves on scale-field *a* belonging to the main lateral-line; *b* = lateral scale-field; *mp* = mandibular plate; other lettering as in Plate I.

PLATE IVA

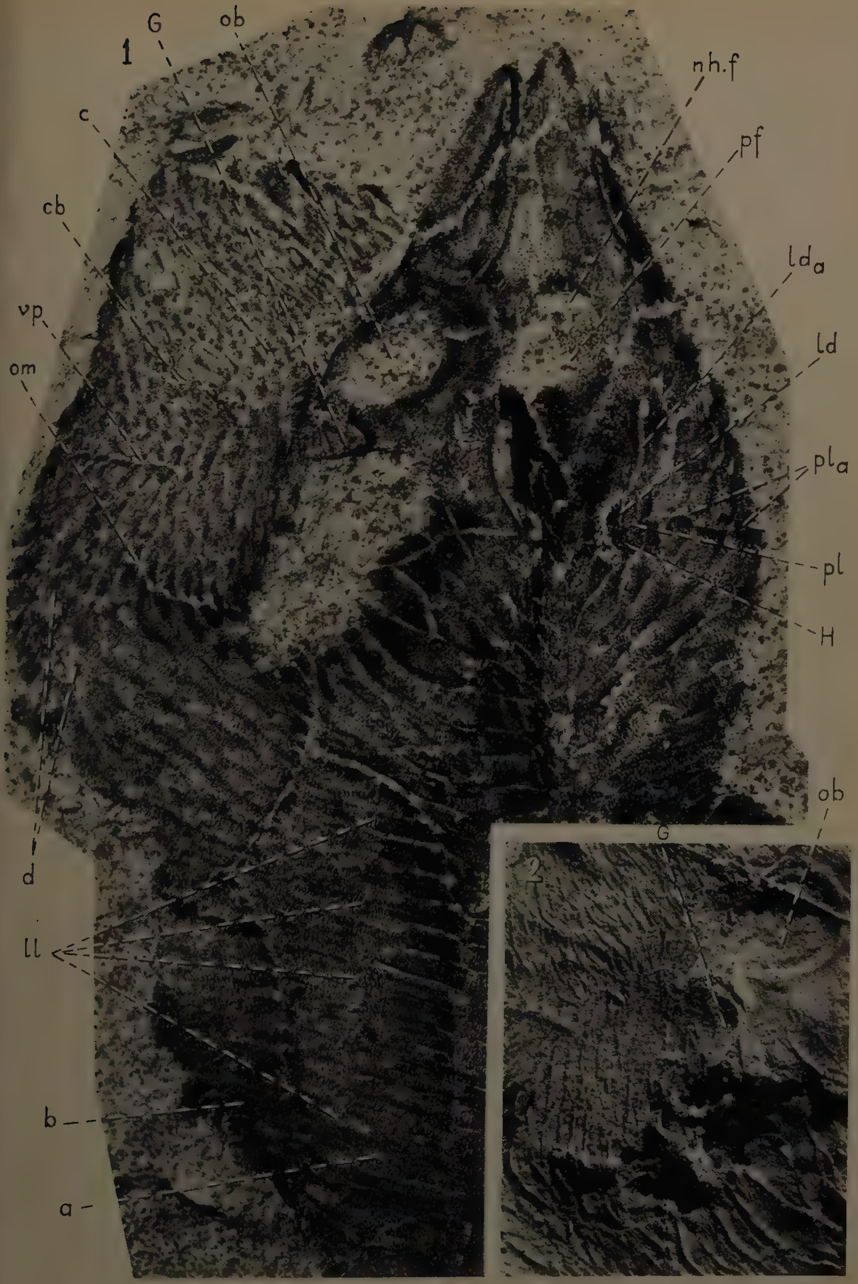


PLATE IV B.

Pharyngolepis kiaeri sp.nov., counterpart of the holotype. Specimen E. 1116 (Pal. Mus. Oslo).

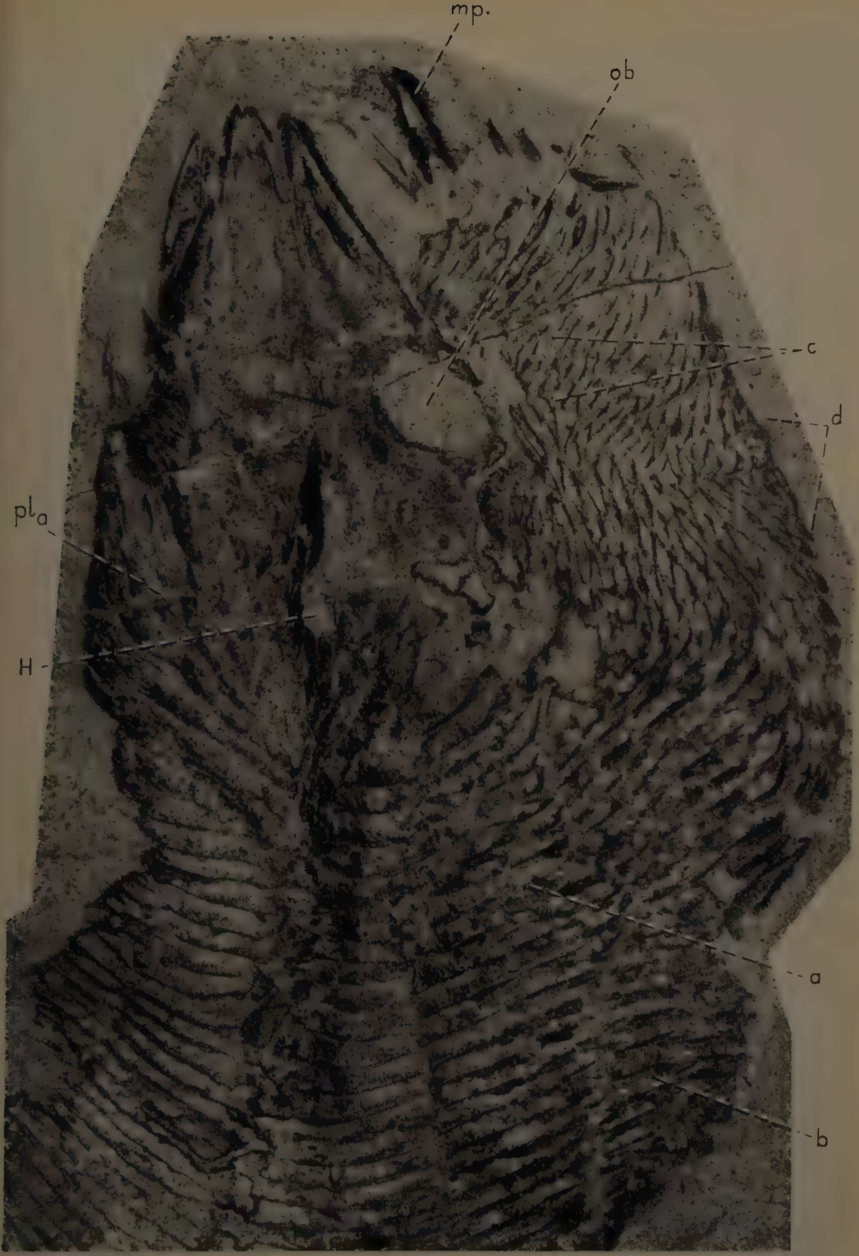

mp.
ob
c
d
pl$_a$
H
a
b

PLATE V.

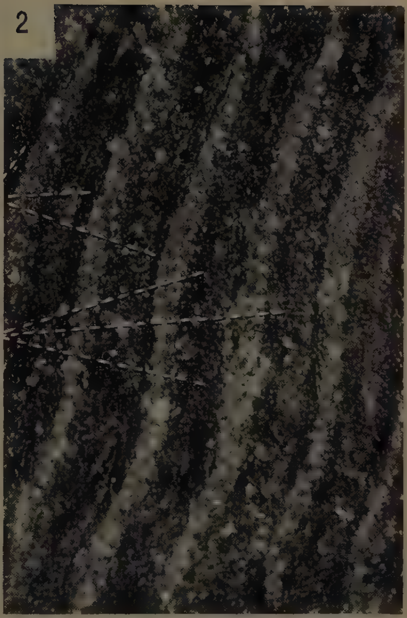
Superficial features of the exoskeleton of certain Anaspids. 1. *Pharyngolepis kiaeri* sp. nov. Specimen E. 1043 (Pal. Mus. Oslo); 2, *Rhyncholepis parvulus* KIAER. Specimen E. 0177 (Pal. Mus. Oslo); 3, *Pterygolepis nitidus* (KIAER). Specimen E. 0567 (Pal. Mus. Oslo); 4, *Birkenia elegans* TRAQ. Unnumbered specimen in the Kelvingrove Museum, Glasgow.

Exoskeleton in basal (internal) view; all X 15, photographed in xylol. The specimens from Ringerike all retain a certain amount of bone substance on the scales which is brownish and translucent, the specimen of *Birkenia* is, except for some highly carbonized remains, an impression in the rock matrix. *lr* = longitudinal, basal ridges of the scales; *st* = superficial tubercles of the exoskeleton.

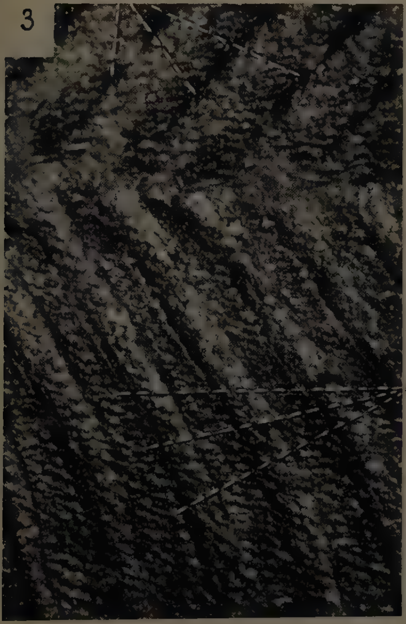
PLATE V

1

2



3



4

PLATE VI.

Pterygolepis nitidus (KIAER), thin section from a dorsal ridge scale of Specimen E. 1041 (Pal. Mus. Oslo) to show the hard tissue of the exoskeleton. Outer margin to the left. X 295. The complete specimen is figured by KIAER (1924) in Plate V.

PLATE VI

MONTMORILLONITT FRA FORTUN I SOGN

Montmorillonite from Fortun in Sogn, West Norway

AV

IVAN TH. ROSENQVIST

Abstract. A highly plastic montmorillonitic breccia rock from Fortun in Sogn is investigated by means of X-ray and chemical methods. The X-ray diagrams shows, a remarkably, strong 001 reflex and assymetric hk-bands. The montmorillonite is considered dioctahedric. The ion-exchange capacity is found to be 128 m.eq./100 grams. Probably, the rock originated through hydro-thermal alterations from anorthositic inclusions below the upper Jotun thrust plane.

Fra A/S Årdal og Sunndal Verk, Fortun Kraftverk, mottok Norges geotekniske institutt i november 1956 en kasse med bergartsprøver fra driftstunnelen mellom Rya og Nausanosi i Fortun, med anmodning om å undersøke hvilken bergart det dreiet seg om. Etter den foreløpige laboratorieundersøkelse reiste forfatteren en tur bort for å besiktige forekomstene.

Prøvene besto av en hvit til lys grå, såpelignende bløt bergart med en del glinsende svovelkiskrystaller. Det var opplyst at bergarten var påtruffet som en halv til en meter brede ganger på tvers av tunnelretningen og at det for øvrig fantes ganger fra 5 til 10 cm tykkelse over en strekning av 5 meter.

Ved laboratorieundersøkelsene viste det seg at bergarten lot seg dispergere i vann til en fin leirlignende oppslemming og at man ved sedimentasjon på denne måten fikk frem et rent, hvitt pulver.

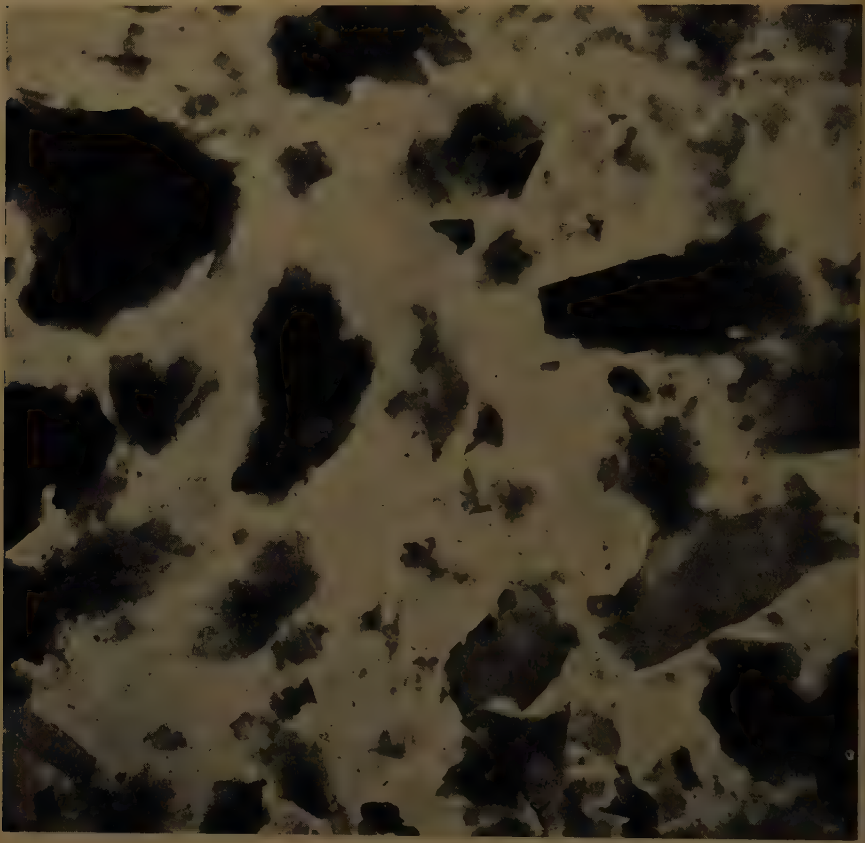


Fig. 1. Elektronmikroskopisk bilde av dispergert bergart fra tunnelen Rya—Nausanosi. 6000 x.

Preparatet er fremkommet uten mekanisk knusing, og viser i det vesentlige uhyre tynne, plateformige mineraler med uregelmessig ytre begrensning. *Electron-micrograph of disperged rock from tunnel Rya–Nausanosi. 6000 x. The specimen was prepared without mechanical crushing and shows the extremely thin, platy minerals with irregular outlines.*

Mikroskopisk undersøkelse.

Svovelkis hadde kornstørrelse opp til ca. 1 cm^3 og forekom ofte i velutviklede jernkorstvillinger. Disse fantes fordelt rundt omkring i den bløte bergart. På samme tid var denne oftest rikt impregnert av uhyre små svovelkiskrystaller. De ikke opake mineraler viste seg å bestå av flakformige mineraler av meget ringe kornstørrelse. Den optiske bestemmelse var derfor vanskelig. Det syntes dog å være et rent monomineralsk pulver som ble oppnådd ved slemming.

Brytningsindeks for aggregat synes å være lik eller litt under 1,51; dobbeltbrytning mellom 0,010 og 0,015. Sannsynligvis er brytningsindeks noe nær *α* ca. 1,505; *β* og *γ* ca. 1,515.

Elektronmikroskopiske undersøkelser ga til resultat at storparten av preparatet besto av uhyre tynne flak med kantlengde ofte vesentlig under 1 mikron og med flaktykkelse av størrelsesorden mellom 30 og 100 Å. (Se fig. 1).

Plastisitet.

Et knust preparat av bergarten uten slemming viste en flytegrense på 185 og en plastisitetsgrense på 55, plastisitetsindeks 130. Det dreier seg derfor om et høyplastisk leirmateriale.

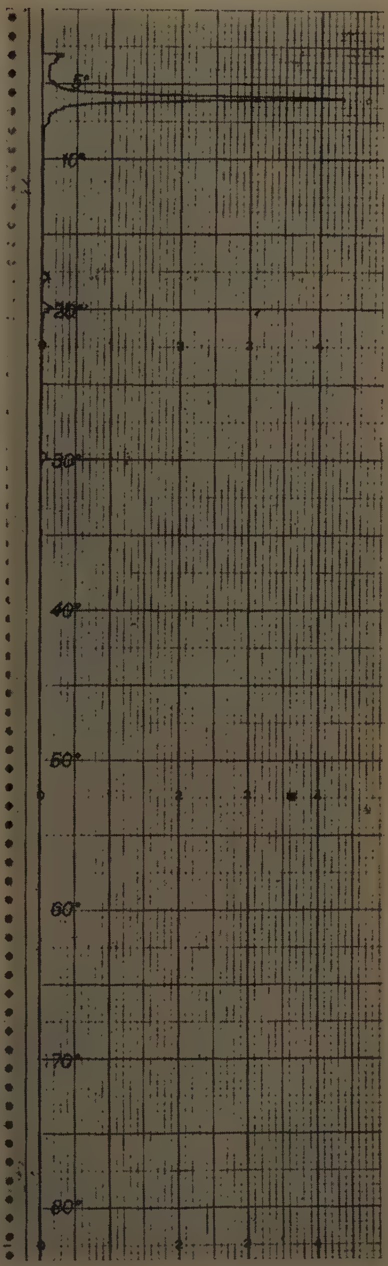


Fig. 2. Røntgenregistram fra 3°–85° av utslemmet pulverpreparat fra Rya, Logaritmisk forsterkning.
X-ray diagram from 3°–85° of a mineral specimen from Rya; Logarithmic intensity registration.

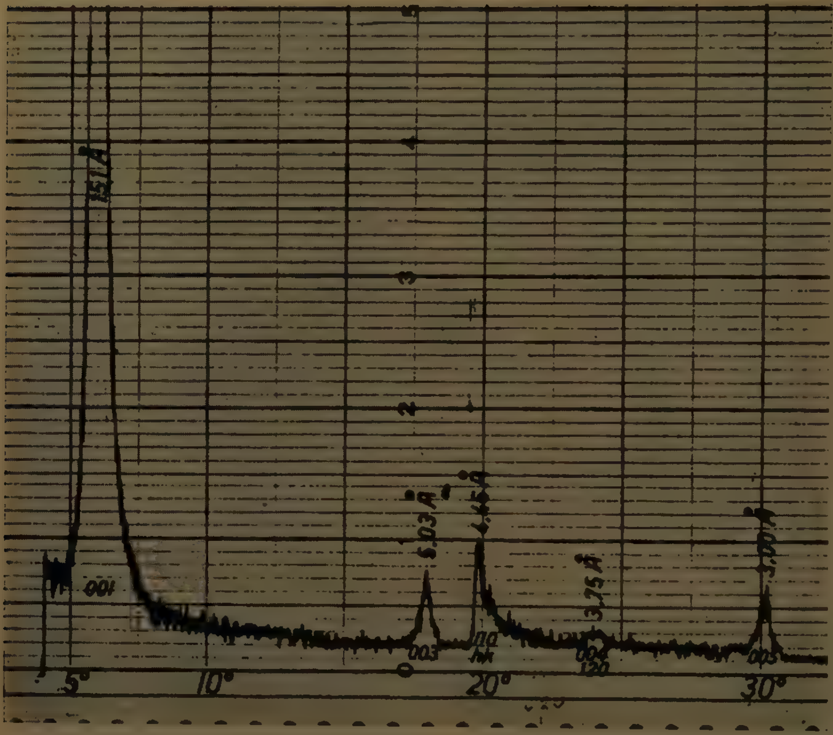


Fig. 3. Røntgenregistram fra 3,5°–32,5°, lineær forstørrelse. Man ser her de utpregete asymmetriske hk-reflekser.
X-ray diagram from 3,5°–32,5°; linear intensity registration. Notice the asymmetric hk-reflexes.

Røntgenundersøkelse.

Røntgenundersøkelser av det utslemmede materiale ga et meget eiendommelig resultat, *idet det naturlige mineral så å si bare hadde en refleks.* I alt ble tatt opp 3 røntgendiagrammer av forskjellige prøver av det naturlige mineral ved hjelp av Philips Recording Spectrometer; 2 av disse med lineær forstørrelse og 1 med logaritmisk forstørrelse. Dessuten ble tatt opp et diagram med glyserolbehandlet substans. Diagrammene viste tydelig forskjell på de interferensmaksima som svarte til basisrefleks og de som svarer til hk-refleks, idet disse siste hadde en utpreget asymmetri. (Se fig. 2–3). Resultatet av utmålingen av de 4 filmer sees av nedenstående oppsetning, der indisering fra montmorillonitt er anvendt og ytterligere angitt D-verdier og linjenes intensitet.

NATURLIG MINERAL.

Ind.	Opptak 1 Lineær registrering		Opptak 2 Lineær registrering		Opptak 3 Logaritmisk registrering	
	D	Int.	D	Int.	D	Int.
001	15,1 Å	10 000	15,0 Å	10 000	15,1 Å	10 000
003	5,03 -	500	4,98 -	300	4,98 -	500
110	4,46 -	880	4,48 -	350	4,51 -	775
004 120	3,75 -	150	—	—	3,74 -	200
005	3,00 -	550	2,99 -	225	2,99 -	625
130 006	2,53 -	200	—	—	2,56 -	400
240 008	1,7 -	100	—	—	—	—
0010 330 060	1,50 -	250	1,50 -	60	—	—
0012 260	1,29 -	100	—	—	—	—

Når det gjelder interferenslinjenes beliggenhet, viser røntgendata betydelig likhet med «beidelitt». Derimot er intensitetsforholdene mellom de enkelte linjer ved mineralet fra Fortun helt ekstreme. Som eksempel sees de tre røntgendata for beidelitt som er publisert av American Petroleum Institute, 1951.

Ind.	Opptak 4 Glyserolbehandl. Logaritmisk registrering	
	D	Int.
001	18,0 Å	10 000
001[1]	15,0 -	170
002	8,9 -	550
003	5,94 -	325
110	4,50 -	1 000
005	3,56 -	650
130	2,58 -	325
240	1,70 -	500
0012	1,50 -	425

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[1] Vermikulitt?

RØNTGENDATA FOR BEIDELITT.

Slock Jock Mine, Idaho		Beidell, Colorado		Hector, California	
d(Å)	I	f(Å)	I	d(Å)	I
15,1	VS	15,2	M	15,8	S
5,03	S	5,05	W	—	—
4,45	VS	4,51	VS	4,57	VS
—	—	—	—	—	—
—	—	3,36	W	—	—
3,02	VS	3,03	W	3,23	W
2,60	VS	2,60	VS	2,08	S
2,49		2,54		2,65	M
2,38	W	2,38	W	2,48	
2,240	VW	2,240	VW	2,285	VW
2,164					
2,090	VW	2,140	VW	—	
1,890	VW	—			
1,694	M	1,700	M	1,748	M
1,654		1,640		1,689	
1,488	VS	1,500	VS	1,527	VS
		1,302		1,320	S
1,284	M	1,285	W	1,301	
1,245	M	1,245	W	1,267	VVW
—	VW	—		—	—
0,970	VW	—		0,990	W
0,862	VW	—		0,878	W

På tross av uoverensstemmelsene i intensitet synes det rimelig å karakterisere materialet fra Fortun som et meget rent diokdahedrisk montmorillonittmineral.

Kjemiske undersøkelser.

Kjemisk analyse av utslemmet materiale utført ved Sentralinstituttet for Industriell Forskning ga følgende resultat, som vist øverst på neste side.

Mineralets spesifikke vekt ble funnet å være 2,62. Dets hygroskopisitet over 4-prosentig natriumkloridoppløsning ble funnet til 16,25%. Preparatet inneholdt 0,091 % svovel og analysen representerer derfor et så å si pyrittfritt preparat.

SiO_2	53,48
Al_2O_3	20,13
Fe_2O_3	0,88
MgO	3,91
CaO	3,64
Na_2O	0,10
K_2O	0,03
H_2O^+	10,85
H_2O^-	6,93
	99,95

Ved beregning av formelen er det tatt hensyn til pyrittinnholdet, idet innholdet av Fe_2O_3 er satt til 0,8. For beregning av analysen er det gått ut fra at man har med en diokdahedrisk struktur å gjøre. Analysen gir på basis av $..O_{10}\ (OH)_2$ følgende resultat:

$$\left.\begin{array}{l} \textit{Oktahedriske lag.} \\ \quad \left.\begin{array}{ll} \text{Mg} & 0{,}42 \\ \text{Al} & 1{,}55 \\ \text{Fe}^{\text{III}} & 0{,}04 \end{array}\right\} \begin{array}{l} 2{,}01 - 0{,}39 \text{ valenser} \\ (\text{OH})_2 \end{array} \\ \\ \textit{Tetrahederiske lag.} \\ \quad \left.\begin{array}{ll} \text{Si} & 3{,}84 \\ \text{Al} & 0{,}16 \end{array}\right\} \begin{array}{l} 4{,}0 - 0{,}16 \text{ valenser} \\ \text{O}_{10} \end{array} \end{array}\right\} - 0{,}55 \text{ valenser.}$$

Utbyttbart.

$$\left.\begin{array}{ll} \text{Ca} & 0{,}26 \\ \text{Na} & 0{,}01 \end{array}\right\} \text{tilsvarende } 0{,}53 \text{ valenser}$$

1,6 H_2O ved 105°.

Til sammenligning kan anføres de to beidelittanalyser som angis av U. Hoffmann og medarbeidere (1955). («Clays and Clay Minerals». — National Academy of Science — National Research Council, Washington 1956):

BEIDELITT I.

$$\left.\begin{array}{l}
\textit{Oktahederiske lag.}\\
\left.\begin{array}{ll}\text{Mg} & 0{,}19\\ \text{Al} & 1{,}82\\ \text{Fe}^{\text{III}} & 0{,}01\end{array}\right\} \begin{array}{l}2{,}02 - 0{,}13 \text{ valenser}\\ (\text{OH})_2\end{array}\\
\textit{Tetrahederiske lag.}\\
\left.\begin{array}{ll}\text{Si} & 3{,}55\\ \text{Al} & 0{,}45\end{array}\right\} \begin{array}{l}4{,}0 - 0{,}45 \text{ valenser}\\ \text{O}_{10}\end{array}
\end{array}\right\} - 0{,}58 \text{ valenser}$$

Utbyttbart.

$\text{Me}^{+}{}_{0,58}\text{nH}_2\text{O}$

BEIDELITT II.

$$\left.\begin{array}{l}
\textit{Oktahederiske lag.}\\
\left.\begin{array}{ll}\text{Mg} & 0{,}27\\ \text{Al} & 1{,}76\\ \text{Fe}^{\text{III}} & 0{,}01\end{array}\right\} \begin{array}{l}2{,}05 - 0{,}15 \text{ valenser}\\ (\text{OH})_2\end{array}\\
\textit{Tetrahederiske lag.}\\
\left.\begin{array}{ll}\text{Si} & 3{,}56\\ \text{Al} & 0{,}44\end{array}\right\} \begin{array}{l}4{,}0 - 0{,}28 \text{ valenser}\\ \text{O}_{9,92}\end{array}
\end{array}\right\} - 0{,}43 \text{ valenser}$$

Utbyttbart.

$\text{Me}^{+}{}_{0,42}\text{nH}_2\text{O}$

DTA og vannavgivning.

Differentialtermisk analyse av utslemmet finstoff ga et diagram som sees av fig. 4. DTA-diagrammet er karakterisert ved sin utpregede dublett ved lav temperatur med to sterke minima mellom 160 og 225°, og de to minima ved 700 og 840°, fulgt av en eksoterm reaksjon. Ifølge P. E. Kerr, og medarbeidere skyldes disse effekter følgende forhold:

Den endoterme effekt ved lav temperatur med den utpregede dublett er karakteristisk for kalsium-montmorillonittene i motsetning

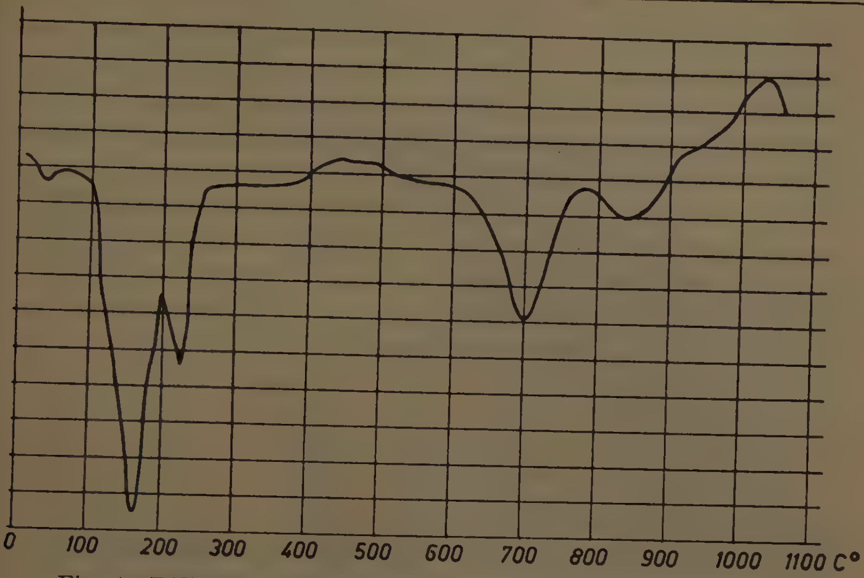

Fig. 4. Differentialanalysediagram av uslemmet finstoff fra Rya.
DTA-diagram of the finest fraction from Rya.

til natrium-montmorillonittene, som oftest har et eneste skarpt minimum.

Den endoterme effekt ved ca. 700° tilskrives tap av hydroksyl og er i det vesentlige en funksjon av kation-hydroksylbindingen. Den er videre en funksjon av krystallinitetsgraden; i dette tilfelle ligger

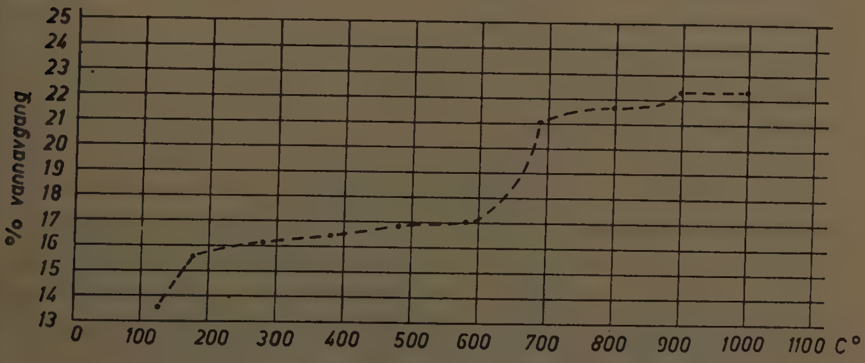

Fig. 5. Vannavgivningskurve for bergarten.
Water given off by heating.

denne endoterme effekt relativt høyt sammenlignet med andre montmorillonittmineraler.

Den neste effekt ved ca. 900° skyldes nedbrytningen av montmorillonittgitteret og er influert av substitusjoner såvel i oktahederlagene som i tetrahederlagene.

Den eksoterme effekt ved høy temperatur tilskrives dannelsen av spinell og er følgelig i det vesentlige avhengig av den kjemiske sammensetning av oktahederlagene.

Vannavgivningen sees av fig. 5. Den stemmer godt med det man kan vente for et montmorillonittmineral.

Ionebytningskapasitet.

Ionebytningsforsøk med ammoniumklorid viste at 120 m.ekv. kalsium kunne ekstraheres av 100 gram materiale; omregnet på materiale tørket ved 105° tilsvarer dette 128 m.ekv./100 gram. Dette utgjør ikke riktig all den kalsium som er funnet i analysen og som ved den oppsatte formel er forutsatt å befinne seg i utbyttbare posisjoner.

Som det fremgår av analysen, er her funnet 3,64 % regnet på lufttørket materiale, dvs. 3,9 % på materiale tørket ved 105° eller temmelig nøyaktig 140 m. ekv./100 gram for leire. Hvorvidt utbytning med ammoniumklorid har vært ufullstendig eller hvorvidt en del av kalsium foreligger i ikke utbyttbare posisjoner eller i form av andre Ca-holdige mineraler, har det ikke vært mulig å avgjøre. Man kan imidlertid med sikkerhet gå ut fra at det ikke finnes nevneverdige mengder med kalsitt eller plagioklas i preparatet.

Geologisk diskusjon.

Angående montmorillonittmineralets opprinnelse, så tyder den geologiske opptreden på at det dreier seg om en hydrotermal dannelse. Ved befaring av forekomsten viste det seg at montmorillonitten forekom som en utpreget breksiebergart tilnærmet parallell skifrigheten i Valdressparagmitten ca. 100 m under hovedskyveplanet for Øvre

Jotundekket. Montmorillonittbergarten inneholdt et stort antall uregelmessig fordelte bruddstykker av den forskifrede sparagmittbergarten. Til dels var også disse sparagmittbruddstykker omvandlet til en leirlignende masse, men de hadde beholdt sin skifrige karakter og stikker ved sin grå farve sterkt av fra den ofte kritthvite montmorillonittbergart.

Da de hydrotermale prosesser som har virket til å danne montmorillonittbergarten i Fortun åpenbart også har angrepet Valdres-sparagmitten, men med et annet mineralogisk resultat, virker det naturlig å tenke seg at montmorillonitten er oppstått ved hydrotermal omvandling av labradorsteinsbreksie. I forbindelse med Øvre Jotundekket finnes tallrike anortosittforekomster og ifølge muntlig meddelelse fra bergingeniør B. Diedrichson, finnes i Jotunheimområdet ofte kritthvite, inneklemte mylonitiserte anortosittbruddstykker i nærheten av hovedskyveplanet. Det er ikke urimelig å anta at slike bergarter kan ha gitt opphav til montmorillonitten ved Fortun. I sin geologiske opptreden skiller denne montmorillonittforekomst seg vesentlig fra de pre- eller interglasiale beidelittholdige forvitringsgrus Barth har beskrevet fra Sørlandet, og også fra den montmorillonittholdige breksie ved Viksnes kobbergrube på Karmøy. Selv om man her finner betydelige likhetspunkter, så har dog Fortunmontmorillonitten en ganske annen renhetsgrad enn hva tidligere har vært beskrevet i Norges.

Økonomisk verdi.

Angående økonomisk utnyttbarhet av montmorillonitten, så synes det ikke som om den forekomst man nu har påtruffet har tilstrekkelig størrelse til å kunne drives med noe utbytte. Ifall det skulle påtreffes større forekomster av samme type i dette området, synes imidlertid den høye renhet å kunne gjøre det mulig å utnytte bergarten industrielt. Norge må i dag innføre all den montmorillonitt som brukes til regenerering av brukte smøreoljer og til rensing av spiselig fett og olje. I en avsperringsperiode, slik vi hadde under siste krig, er montmorillonitt en utpreget mangelvare.

SUMMARY.

By the tunnel works for Fortun Hydro-Electric Power Station in Sogn, a peculiarly soft rock was met with. Microscopic investigations showed flaky minerals of a very small size. The plasticity of the crushed rock was high, PI 130. X-ray investigations showed great similarity to dioctahederic montmorillonite, a remarkably strong 001 reflex and asymmetric hk-bands. Chemical analyses proved it to be mainly a magnesium aluminium silicate. The ionexchange capacity was high, 128 m eq./100 grams. The rock contains altered pieces of Valdres sparagmite. Most possibly the montmorillonite represents hydrothermally altered mylonitized anorthosite, below the main thrust plane of the upper Jotun Nap.

The economical value of the occurrence seems doubtful.

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POLLENANALYTISK DATERING AV ET MYRFUNNET ILDSTED FRA TRYVASSHØGDA I OSLO

Pollen-analytical dating of a stony hearth found in a bog on Tryvasshøgda in Oslo

AV

ULF HAFSTEN

Abstract. During the ground work for the Tryvann Stadium in Oslo 1933/34 a hearth consisting of 5–6 burned stones standing on edge with a handful of ash between them, was found at the bottom of a 3 m deep bog. Hoping that this find at some time might be dated pollen-analytically Dr. Gunnar Holmsen, geologist at the Norwegian geological Survey, on the 6th of January 1934 took out a profile with a sampling interval of 20 cm. After the results of my pollen–analytical investigations on the late Quaternary development in the inner Oslofjord area had been published in 1956, Holmsen sent these samples to me, hoping that I would be able to date the find.

By comparing the pollen diagram prepared on the basis of this profile (see Fig. 1) with the standard pollen diagram for the inner Oslofjord area (see Fig. 2) the hearth (located at the bottom of the diagram) may be coincident with the Sub-Boreal minimum of the mixed oak-forest occurring in a series of the diagrams from the Oslo area. As this minimum is supposed to represent a comprehensive late Neolithic clearance phase referring to the Flint Dagger period, the hearth find from the Tryvann Stadium probably dates to about 1500 B.C. The decrease of the amount of non-arboreal pollen (see the TOTAL-diagram) at the Sub-Boreal–Sub-Atlantic (VIII–IX) transition is assumed to be a consequence of the climatic deterioration, allowing the Norway spruce, with its very spreading and shallow root system, to colonize even Tryvasshøgda. This syenitic-granitic hill district is namely covered by a rather sparse ground- and ablation-moraine, poor in plant nutrients and having a small water-holding capacity. Because hunting and fishing played an important part

in the economy of the farmers during the Younger Stone Age and the Bronze Age, agricultural activity could take place during the Sub-Boreal period even in this high-lying, unfavourable area. This dating also seems to agree very well with the stratigraphy, as the increasing wetness represented by the transition from wood peat into *Sphagnum* peat at 230 cm below surface probably corresponds to Granlund's RY IV, ca. 1200 B.C.

The find of a typical pollen grain of holly (*Ilex aquifolium*) is of special palaeobotanical interest, as only one subfossil pollen grain of this oceanic species has formerly been recognized from eastern Norway, viz. from a Sub-Boreal sample in Vålertjern in the Mjøs region (cp. Hafsten 1956). There is now reason to assume that even holly grew in the inland districts during the Post-Glacial warmth period. It is, as a matter of fact, most likely that holly grew in the favourable localities in the lowland, at the foot of the hills, and that pollen and pollen-bearing insects have been carried up in the hills by the strong convection currents which often occur on hot summer days. Using the methods adopted by Iversen (see Fig. 3) the *Ilex* find indicates that the temperature for the coldest month (January) must have been ca. 3.5 °C or more higher than at the present time.

Funnforhold og feltarbeid

I oktober 1956, like etter at resultatene av mine pollenanalytiske undersøkelser over den senkvartære utvikling i det indre Oslofjordsområdet var blitt publisert (Hafsten 1956), fikk jeg fra dr. Gunnar Holmsen ved Norges geologiske undersøkelse sendende en serie på 13 torvprøver som var tatt der Tryvann stadion nå ligger. Dette er like sydvest for Tryvannstårnet i meget nær 500 m høyde. Holmsen skriver at prøvene ble tatt 6. januar 1934, etter foranledning av en meddelelse fra ingeniør Østensvig i Oslo kommune. Under planeringsarbeide for Tryvann stadion var det mellom jul og nyttår blitt funnet et ildsted på bunnen av nevnte myr.

Etter å ha besøkt stedet 3. januar 1934 skriver Holmsen følgende i sin dagbok: «Av ildstedet var intet tilbake. Arbeiderne hadde funnet 5–6 oppreiste stener på bunnen av myren som her var 3 m tykk. I mellom stenene lå en håndfull aske. De var aldeles sikre på at stenene var brent, og at det hadde vært et ildsted her. Men alt sammen var kjørt ut på tippen og ødelagt. De hadde lagt til side noen forkullede stubber, men om disse stammet fra et kunstig ildsted eller fra skogbrann, var jeg i usikkerhet om. Underlaget for myren er berggrunn eller sandblandet leir av liten mektighet. Der såes litt blåleir, seigt og fritt for stener, og i sanden var klumper av et sterkt grønnfarget leir».

6. januar reiste så Holmsen atter opp til myra og «tok pollenprøver fra den sjakt, hvori ildstedet ble funnet». Prøvene ble tatt for hver 20 cm, fra 60 cm dyp til bunnen som lå 300 cm under overflaten. Prøven fra 200 cm dyp ble ødelagt. Holmsen gir følgende beskrivelse av profilet på det sted prøvene ble tatt (sml. kolonnen til venstre i fig. 1):

Ovenfra til 230 cm: Lyngrik hvitmosetorv.
Fra 230 til 300 cm: Skogsmyrtorv med røtter av bjerk og furu.
- 300 - 320 - : Sand og sandblandet leir.

Laboratoriearbeid.

Laboratoriearbeidet er utført vesentlig etter de prinsipper som er angitt av Fægri & Iversen (1950). Samtlige prøver er blitt farget med fuchsin. Det tilsendte materiale omfattet også en prøve fra laget med sand og sandblandet leir, men den var på det nærmeste pollentom. Ellers inneholdt prøvene rikelig og vel oppbevart pollen.

Analysene er fremstilt grafisk i et sammensatt pollendiagram (se fig. 1) som er konstruert på samme måte som diagrammene i min 1956-avhandling. For å spare plass er dybdeskalaen her bare tegnet i halv målestokk av hva som er gjennomført i de sistnevnte diagram. Dette gjør at kurveforløpet blir mer steilt. Regnet fra venstre har man først dybdeskala og snitt gjennom lagfølgen. Analyseresultatene er så angitt i 4 partielle diagram: 1. QM-diagrammet, et spesialdiagram i forstørret målestokk over ekblandskogen og dens konstituenter, 2. AP-diagrammet, grunndiagrammet, som viser forholdet mellom de forskjellige treslags pollenmengder, 3. TOTAL-diagrammet, et oversiktsdiagram som viser forholdet mellom pollenmengdene av røslyng og vindbestøvende urter (NAP) på den ene siden og treslagene (AP) på den annen og 4. NAP-diagrammet, et eget feltskiktdiagram som vesentlig omfatter pollen av vindbestøvende urter og røslyng. Til slutt er pollensonene angitt. De følger Jessen's inndeling, slik at sone VIII tilsvarer den subboreale og sone IX Blytt-Sernander's subatlantiske klimaperiode. En del pollentyper forekommer for sparsomt til å kunne fremstilles grafisk ved egne pollenkurver, og prosentverdiene

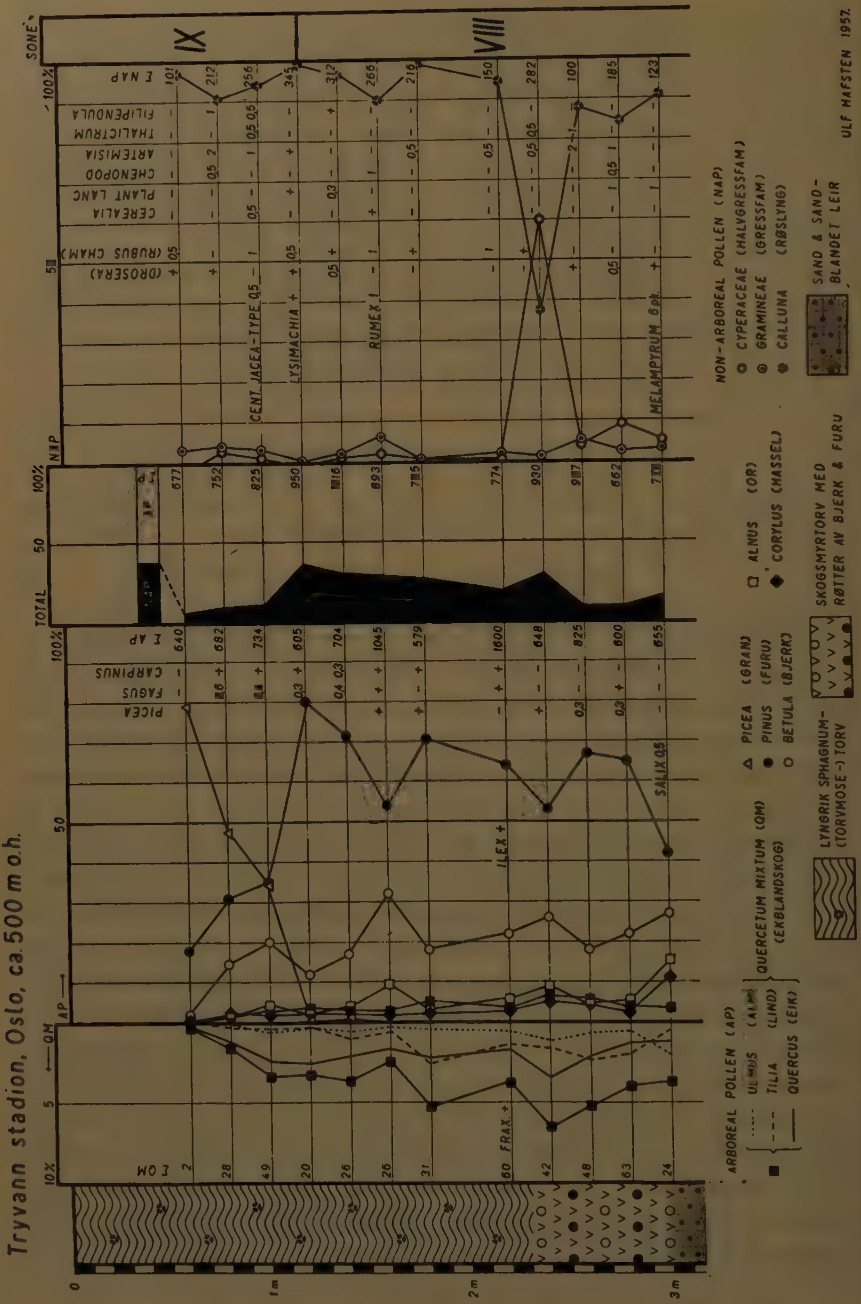


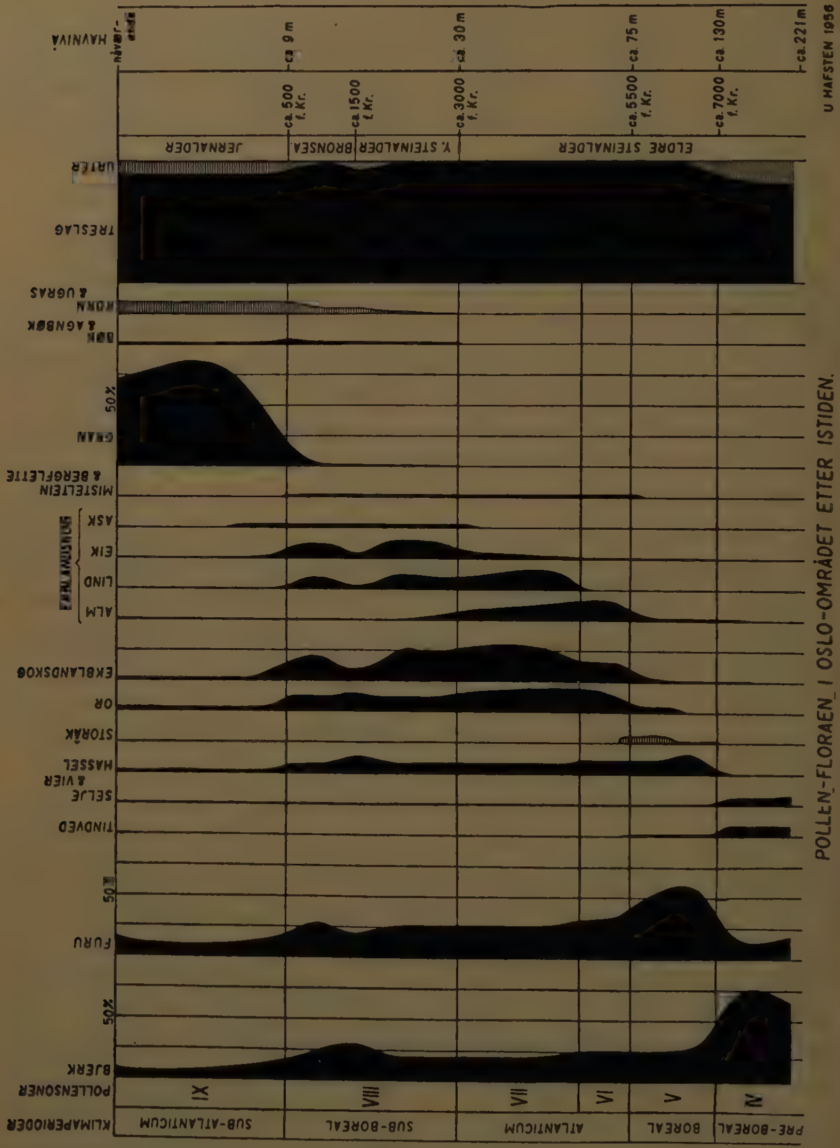
Fig. 1. Pollendiagram fra Tryvann Stadion, Tryvasshøgda i Oslo.
Pollen diagram from the Tryvann Stadium, Tryvasshøgda in Oslo.

for dem er derfor angitt i kolonner eller skrevet inn der de hører hjemme. *Drosera* (soldugg) og *Rubus chamaemorus* (molte) som er insekt- eller selvbestøvere er ikke medregnet i NAP-summen, men er prosentberegnet av summen av urte- og treslagspollenet (NAP + AP). Derimot er *Filipendula* (mjødurt) her tatt med i beregningsgrunnlaget for urtepollenet.

Datering av ildstedet.

I overensstemmelse med resultatene av mine tidligere undersøkelser i Oslotrakten (se oversiktsdiagrammet i fig. 2) kan det ikke herske noen tvil om at grensen mellom pollensone VIII og IX (mellom subboreal og subatlantikum) faller omtrent i 120 cm dyp. Vi kjenner her igjen den karakteristiske, raske stigningen for gran-pollenkurven, samtidig med den endelige nedgangen for ekblandskogs-pollenet. Det er disse trekk som avslører den katastrofale klimaforverringen som fant sted ved overgangen mellom bronse- og jernalderen, ca. 500 år f. Kr. Klimaet slo den gang ganske plutselig om fra å være varmt og tørt til å bli kaldt og fuktig. Dette førte til en rask desimering av varmekjære løvtrær, særlig ekblandskogen, og til at granen i løpet av kort tid fullstendig erobret grunnen. Mine undersøkelser i Oslotrakten har vist at det eksisterte enkelte spredte grupper av gran allerede under varmetiden, men det er først etter klimaforverringen granen blir konkurransedyktig og tar området i besittelse.

Den betydelige nedgangen for urte- og lyngpollen, resp. økning av treslagspollen (se TOTAL-diagrammet), samtidig med gran-stigningen, viser at skogdekket på Tryvannshøgda nå var i ferd med å bli meget tettere. Men i oversiktsdiagrammet for Oslotrakten viser treslagspollenet tilbakegang på denne tid. Denne forskjellen henger utvilsomt sammen med forskjelligheter i jordbrunnsforholdene. Oversiktsdiagrammet er nemlig utarbeidet vesentlig på grunnlag av undersøkelser innen den fruktbare kambrosilur-provinsen, mens Tryvasshøgda hører med til det tilgrensende syenitt — granitt-området. Mens dette høytliggende område bare har et sparsomt og skrint morenedekke, har kambrosilur-strøkene, som for det meste ligger under marin grense (d. v. s. under 220 m o. h.), rikelig med fruktbare løsavleiringer (terasser og leiroppfyllinger), som selv under den tørre subboreale



POLLEN-FLORAEN I OSLO-OMRÅDET ETTER ISTIDEN.

periode trolig har kunnet by skogen gode betingelser. Men det var også disse strøkene som var best egnet for oppdyrking. Nedgangen for treslagspollenet i oversiktsdiagrammet synes derfor først og fremst å være et utslag av intensiveringen av jordbruket. Men åsene innenfor var uegnet for jordbruk og skogen fikk her for det meste stå i fred for menneskelig inngrep. Vegetasjonsutviklingen her er derfor først og fremst klimatisk betinget. Det foreliggende pollendiagram fra Tryvasshøgda avslører da også en vegetasjonsutvikling som på det nøyeste stemmer overens med den generelle klimautvikling for de perioder det her dreier seg om.

Den relativt rikelige forekomsten av urte- og lyngpollen (se NAP-silhuetten i TOTAL-diagrammet) sammen med den overlegne dominansen av furu-pollen i treslags- eller AP-diagrammet nedenfor sonegrensen VIII–IX, viser at Tryvasshøgda før klimaforverringen var kledd med temmelig åpen furuskog. Mer fuktighetskrevende treslag som bjerk, or og hassel, som regnes som like store pollenprodusenter som furuen, spiller derimot en svært beskjeden rolle i pollenfloraen på denne tid. Denne fordelingen av treslagspollenet tyder på utpreget tørre vekstbetingelser. Furuen er som kjent det av våre treslag som er best tilpasset tørre voksesteder. De høye verdier for røslyng (*Calluna*) i NAP-diagrammet kunne for så vidt også tas som en indikasjon på tørre vekstbetingelser. Men det faktum at røslyng-dominansen varer ved også i sone IX, gjør at vi ikke kan se bort fra at de rikelige lyngpollenverdiene er lokalt betinget og først og fremst skyldes lyngvekst innen selve myrområdet. Dette stemmer også godt med at Holmsen karakteriserer torven som lyngrik. Selv om ekblandskogens trær — alm, lind, eik og ask — er langt sparsommere pollenprodusenter enn furu, bjerk, or og hassel, viser de lave pollenprosenter at disse treslag

←

Fig. 2. Oversikt over pollenfloraen i Oslotrakten gjennom de siste 10 000 år. Konstruert på grunnlag av de 26 enkeltdiagram fra Oslo, Bærum, Asker, Røyken og Nesodden som er publisert i HAFSTEN 1956. Sonebetegnelsene er noe forandret. Strandlinjens beliggenhet over nåværende middelvannstand er angitt lengst til høyre.

Standard diagram for the inner Oslofjord region, constructed on the basis of the 26 pollen diagrams from Oslo, Bærum, Asker, Røyken, and Nesodden, published in HAFSTEN *1956. The zone numbers are somewhat altered. Data for the shore-line displacement, in metres above present sealevel, are indicated to the very right.*

likevel bare spilte en helt underordnet rolle i skogdekket. Vi må også regne med at noe av dette pollenet er kommet hit opp med oppadgående luftstrømmer fra lavlandet like sønnenfor, for der spilte nemlig ekblandskogen en ganske viktig rolle under varmetiden. Da ekblandskogen som kjent stiller forholdsvis store krav til voksestedet, harmonerer disse lave verdier meget godt med det karrige jordsmonn på Tryvasshøgda.

Da den fuktige og kalde klimatypen satte inn på overgangen til subatlantisk tid, var ikke lenger fuktigheten noen minimumsfaktor, selv ikke i åstraktene med deres grunne jordsmonn. Men under disse klimaforhold var furuen og de kuldskjære løvtrærne langt mindre konkurransedyktige, og det synes ikke å ha vart særlig lang tid før granen var blitt det helt dominerende treslaget i området. I og med at det nå var fuktighet nok i jorden, kunne granen med sitt grunne, horisontale rotsystem danne sammenhengende skog, også i åstraktene. Dette er utvilsomt forklaringen på at skogdekket her ble betydelig tettere etter klimaforverringen.

Åpenbart er ingen eldre sonegrense enn VIII–IX representert i diagrammet. Riktignok kunne nedgangen for alm, samtidig med den ubetydelige stigningen for lind og eik omkring 290 cm dyp, minne litt om de trekk som karakteriserer sonegrensen VII–VIII (se fig. 2 eller Hafsten 1956 s. 78), men forekomsten av smalkjempe (*Plantago lanceolata*) under dette nivå (se bunnprøven) gjør det ikke særlig sannsynlig. Det ser nemlig ut til at smalkjempen kom til landet først med åkerbrukskulturen, som ifølge mine undersøkelser i Oslotrakten synes å kunne spores tilbake til sonegrensen VII–VIII. Ildstedet er med andre ord eldre enn sonegrensen VIII–IX, men sannsynligvis yngre enn sonegrensen VII–VIII. Det daterer seg altså til den subboreale periode (ca. 3000–500 år f. Kr.).

Hva den nærmere datering angår, er det naturligvis vanskelig å trekke sikre konklusjoner på grunnlag av en prøveserie som denne, hvor prøvene bare er tatt for hver 20 cm. (Ved moderne pollenanalyser brukes en prøveavstand på 5 cm eller mindre). Men det forhold at ekblandskogskurven (se QM-diagrammet) viser en tydelig nedgang fra 240 cm dyp mot bunnen, tyder på at vi her har en parallell til det subboreale QM-minimum som jeg har påvist i en rekke diagram fra Oslotrakten (se fig. 2 eller Hafsten 1956 s. 81 og 108). Da dette «QM-hakket» i mange diagram faller sammen med tydelige maksima for urtepollenet, særlig gress (*Gramineae*), men også korn (*Cerealia*) og ugressarter som vi vet er knyttet til åkerbrukskulturen, ligger det nær å slutte at dette QM-minimum er kulturbetinget og ikke klimatisk. Forekomsten av tydelige kullag i forbindelse med dette QM-hakket peker da også direkte hen på en storstilet skogrydning ved hjelp av svedjebrann. En slik omfattende rydning omtrent midt i subboreal tid synes å passe godt med den voldsomme ekspansjonen som fra arkeologisk hold hevdes å ha funnet sted i siste avsnitt av yngre steinalder, i den såkalte dolktid (se nærmere om dette i HAFSTEN 1956 s. 108).

I diagrammet fra Tryvasshøgda viser hverken gress- (se NAP-diagrammet) eller urtepollenet som helhet (se TOTAL-diagrammet) noen slik respons til de lave QM-verdiene i de nederste spektrene. Men den isolerte forekomsten av pollen av ugress som smalkjempe (*Plantago lanceolata*) og melde (*Chenopodium*) i prøvene fra 280 og 300 cm dyp (se kolonnene i NAP-diagrammet) understøtter i høy grad idéen om at det virkelig er den nevnte dolktidsfasen som her dokumenterer seg. Denne antagelse støttes for så vidt også av den forholdsvis rike forekomsten av marimjelle (*Melampyrum*) i spektret fra 300 cm dyp. Det har nemlig vist seg at marimjellen har en tendens til å opptre ekstra rikelig etter skogbrann.

For oss kan det synes merkelig med åkerbruk på Tryvasshøgda hvor jordsmonnet er så skrint. Men for datidens folk, for hvem jakt og fiske kanskje spilte like stor rolle som jordbruk og fedrift, er det ikke så rart at dyrkning fant sted selv i de høytliggende og mindre fruktbare åsområdene. Mitt pollendiagram fra Fuglemyra som ligger 401 m over havet vitner om at det også på Vettakollen ble dyrket korn i subboreal tid (se HAFSTEN 1956 s. 112 og pl. 2). I diagrammet fra Tryvasshøgda mangler som nevnt kulturpollenet i de spektrene som svarer til regenerasjonsfasen for ekblandskogen, men det dukker opp igjen i forbindelse med den endelige nedgangen for ekblandskogen i slutten av den subboreale periode og danner en ny fase 160–100 cm under overflaten. Mangelen på sikre kulturindikatorer i de to øverste prøvene tyder imidlertid på at dyrkningen her oppe endelig ble oppgitt først i begynnelsen av subatlantisk tid.

Dateringen av ildstedet til siste avsnitt av steinalderen synes også å være i full overensstemmelse med lagfølgen i profilet (se stratigrafikolonnen lengst til venstre i diagrammet). Det ca. 70 cm tykke laget skogsmyrtorv med røtter av bjerk og furu, som hviler på det minerogene underlaget, viser at det her opprinnelig var en skogbevokst myr eller sump. Men omslaget til lyngrik *Sphagnum*-torv 230 cm under overflaten viser at det så fant sted en forsumpning, med drukning av skogen og invasjon av torvmoser. Det er muligens bare denne rent lokale overgang fra skogsmyr til skogbar torvmosemyr som er grunnen til at urtepollenet fra nå av blir mer dominerende i TOTAL-diagrammet. Det voldsomme utslaget i kurven for halvgress (*Cyperaceae*), 240 cm under overflaten, kan også meget vel stå i forbindelse med denne forsumpningen. Men siden det dreier seg om bare én prøve, kan vi ikke se bort fra at denne fluktuasjonen bare skyldes rent lokal overrepresentasjon av *cyperacé*-pollen. Man kan ikke se bort fra at en slik forsumpning kan ha oppstått ved at bassenget på en eller annen måte var blitt demmet opp, men jeg holder det for vel så sannsynlig at denne forsumpningen skyldes en forandring av klimaet i fuktigere retning. Som kjent mente Granlund (1932) å kunne påvise minst 5 klimatisk betingede forsumpningshorisonter eller «rekurrensytor» (RY'er) i syd- og mellomsvenske høgmoser: RY V — ca. 2300 f. Kr., RY IV — ca. 1200 f. Kr., RY III — ca. 600 f. Kr. (svarende til overgangen mellom subboreal og subatlantisk tid), RY II — ca. 400 e. Kr. og RY I — ca. 1200 e. Kr. Det ligger nær å parallellisere den påviste forsumpningshorisonten i profilet fra Tryvasshøgda med Granlund's RY IV, ca. 1200 f. Kr. Da grensen mellom yngre steinalder og bronsealderen vanligvis settes til ca. 1500 f. Kr., passer en slik tolkning av forsumpningsfasen aldeles utmerket med dateringen av ildstedet til dolktid.

Et nytt pollenfunn av kristtorn fra Østlandet.

Av spesiell plantehistorisk betydning er det at denne undersøkelsen har avslørt nok et subfossilt pollenkorn av kristtorn (*Ilex aquifolium*) fra Østlandet. Under analyseringen av prøven fra 220 cm dyp i prøveserien fra Tryvasshøgda dukket det nemlig opp et subprolat, clavat, tricolpat pollenkorn med tydelig margo. Prøven er som alle de andre behandlet etter Erdtman's modifiserte acetyleringsmetode og pollenkornet målte 36 × 28 μ. Det kan ikke herske tvil om at dette pollenkornet refererer seg til *Ilex*, og dermed er pollenkorn nummer 2 av dette oseaniske treslaget påvist fra Østlandet.

Som beskrevet i min 1956-avhandling, ble det første subfossile *Ilex*-pollenkorn fra denne landsdelen påvist under analyseringen av prøveserien fra Vålertjernet like sydøst for Stange i Hedmark. Også dette funnet daterte seg til subboreal tid (sone VIII). Av grunner som er anført i nevnte avhandling lar dette pollenkornet seg vanskelig bortforklare som forurensning i laboratoriet. Det er heller ikke særlig stor sannsynlighet for fjerntransport fra Sør- eller Vestlandskysten. Kristtornen bestøves nemlig av bier og er som insektbestøvere flest en sparsom pollenprodusent. Som eksempel på hvor lite kristtornpollenet i virkeligheten gjør seg gjeldende i pollenregnet, selv i de strøk hvor kristtornen idag er alminnelig, kan nevnes at FÆGRI under sine omfattende pollenanalytiske undersøkelser på Vestlandet hittil kun har truffet på 4 *Ilex*-pollenkorn (3 fra subboreal og 1 fra tidlig subatlantisk tid). Selv på grunnlag av dette ene *Ilex*-pollenkornet fra Vålertjern, var det således grunn til å slutte at kristtornen virkelig hadde vokst i Mjøstraktene i subboreal tid. Men sett fra et økologisk synspunkt, virket det nærmest utrolig at denne oseaniske arten, hvis nordøstgrense i dag går ved Dypvåg i Aust-Agder, noensinne skulle ha hatt vekstbetingelser så langt inne i landet. Ifølge Iversen's undersøkelser (1944) er nemlig kristtornens utbredelse begrenset til strøk der middeltemperaturen for kaldeste måned ligger på ÷ ½° eller over (se fig. 3). Da januar-midlet for Mjøstraktene i dag ligger under ÷ 6°, betyr altså *Ilex*-funnet fra Vålertjern at middeltemperaturen for kaldeste måned må ha vært minst 5° høyere i subboreal tid enn i dag. Dette er en langt høyere vintertemperatur enn vi hittil har regnet med for varmetiden. Men også det forhold at et pollenkorn av en annen oseanisk art, nemlig bergflette (*Hedera helix*), forekom i denne prøveserien (fra tidlig atlantisk tid), peker i retning av usedvanlig høye vintertemperaturer i innlandet under den postglasiale varmetiden. Ifølge Iversen's undersøkelser må nemlig middeltemperaturen for kaldeste måned ligge tydelig over ÷ 2° forat bergflaten skal kunne trives. Nå viser mine undersøkelser at denne oseaniske klatrebusken var ganske alminnelig i Oslotrakten under varmetiden, men det er likevel et ganske betydelig sprang herfra til Mjøstraktene. På grunnlag av disse

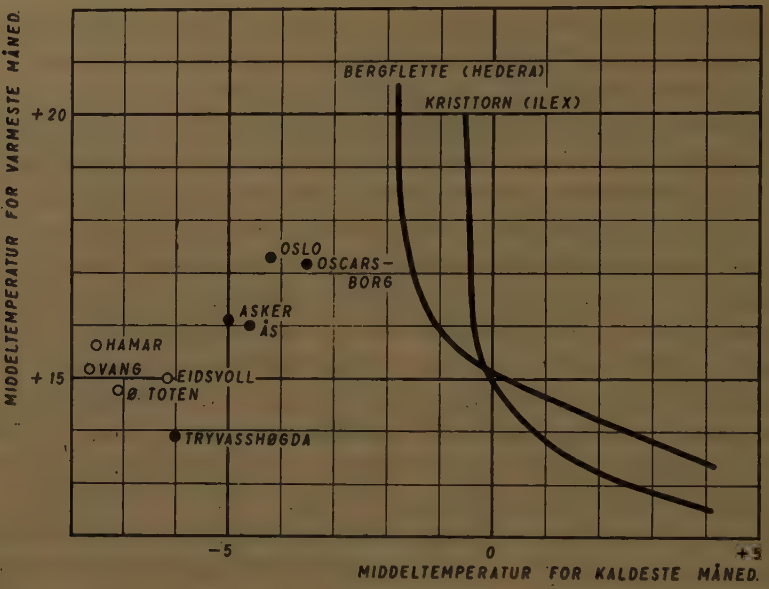


Fig. 3. IVERSEN's termiske korrelasjonsdiagram (omvendt) med grensekurver for bergflette (*Hedera helix*) og kristtorn (*Ilex aquifolium*). Inntegnet en rekke meteorologiske stasjoner fra Oslo-området (prikker) og Mjøs-traktene (ringer). IVERSEN's *thermal correlation diagram (inverted) with limit curves for ivy (Hedera helix) and holly (Ilex aquifolium). Inserted are some meteorological stations from the inner Oslofjord area (dots) and the Mjøs region (circles).*

sparsomme pollenfunn våget jeg ikke i 1956 å slutte at bergflette og kristtorn noen gang hadde vokst i Mjøstraktene. Hvis kristtornen virkelig hadde vokst her oppe, var det jo nokså påfallende at ikke et eneste subfossilt *Ilex*-pollenkorn var blitt observert fra Osloområdet, enda jeg herfra hadde sett gjennom noe slikt som 2.5 millioner treslagspollenkorn (AP) fra 24 forskjellige myrer og tjern vesentlig fra de lavereliggende kambrosilur-strøkene i Oslo, Bærum, Asker og Røyken. Med *Ilex*-funnet fra Tryvasshøgda er imidlertid sannsynligheten for at kristtornen en gang virkelig har vokst i innlandet blitt langt større, for heller ikke dette pollenkornet lar seg bortforklare som forurensning eller fjerntransport. Også denne prøven ble nemlig preparert og analysert utenom blomstringstiden for kristtorn, henholdsvis 2/2 og 9/2 1957.

Imidlertid kan det virke noe merkelig at pollen av kristtorn skulle dukke opp i en prøve nettopp fra denne høytliggende myra. For selv om temperaturinversjoner er nokså vanlige, har Tryvasshøgda et januar-middel som ligger nesten 2° lavere enn Oslo. Dette trekk er for øvrig ikke enestående. I prøveserien fra Fuglemyra på Vettakollen, som ligger 401 m over havet, observerte jeg nemlig *Hedera*-pollen i ikke mindre enn 3 (tidlig atlantiske) prøver. Av prøveseriene fra lavlandet er det bare Hogstadvann i Asker (160 m o. h.) som har et større antall prøver med pollen av bergflette enn Fuglemyra. Det er mulig at disse eiendommelige forhold henger sammen med de sterke oppadgående luftstrømmer (konveksjonsstrømmer) som ofte oppstår på varme dager. Det må jo nettopp ha vært i de gunstige, sydeksponerte skrentene ved foten av de innenforliggende åsene og kollene at ekstremt varmekrevende arter som bergflette og kristtorn eventuelt har hatt betingelser for å klare seg. Og her har det neppe vært til å unngå at pollen, eventuelt insekter med pollen, er blitt ført til værs med de sterke konveksjonsstrømmene og således har havnet i høyereliggende myrer og tjern. Dermed kan vi, ved våre klimahistoriske slutninger, gå ut fra de lavereliggende meteorologiske stasjoner.

Som det fremgår av fig. 3, må middeltemperaturen for kaldeste måned (januar-midlet) likevel ha vært ca. 3.5° høyere under subboreal tid enn i dag forat kristtornen skal ha kunnet vokse her. Dette er 1° mer enn utledet på grunnlag av den subfossile forekomsten av *Hedera*-pollen (se HAFSTEN 1956 s. 87). I tilfelle kristtornen likevel skulle ha vokst på selve Tryvasshøgda, kommer vi derimot opp i omtrent samme verdi som utledet på grunnlag av *Ilex*-funnet fra Hedmark, nemlig minst 5° høyere januar-middel enn i dag. Ved betraktninger som disse må man imidlertid være oppmerksom på at temperaturforholdene i slike kuperte strøk som det her dreier seg om i utpreget grad er avhengig av eksposisjonen og derfor varierer sterkt fra sted til sted. Så lenge man ikke har temperaturdata fra selve stedet hvor det er grunn til å tro at disse planter har vokst, vil paleoklimatiske slutninger av denne art bare være av begrenset verdi. Iversen stiller da også ganske bestemte krav til de meteorologiske stasjoner som bør brukes ved betraktninger av denne art. Av de inntegnede stasjoner er det således bare Oscarsborg som er tatt med i Iversen's liste over anvendte stasjoner.

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Trykt desember 1957

NOTISER

Iakttagelser av isskuring inom västliga delar av den nord-norske strandflaten.

Av

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Under pågående glacialgeologiska undersökningar vid Nordlandskusten har intresse bl.a. ägnats glacialskulpturen på strandflaten. Härvid har ett antal utpräglat västliga lokaler besökts. Då några av de iakttagelser, som härvid gjorts, kunna vara av mera allmänt intresse — jag tänker då speciellt på den alltjämnt öppna frågan om nedisningens omfattning mot väster och det därmed sammanhängande problemet om eventuell övervintring av växter på isfria områden — skola i form av detta meddelande några observationer tagas upp till kort behandling.

Ögruppen Sklinna (se kartan fig. 1) utgör den yttersta delen av strandflaten i trakten Nordtröndelag–Sörhelgeland. I ögruppen ingår ett antal mindre öar uppbyggda av en ljus, rödaktigt grå och finkornig, plagioklasgranit. På det geologiska generalkartet Vega (REKSTAD 1917) finnes ej upptagen någon angivelse om isreffling inom ögruppen.

Vintern 1956 besökte jag under några dagar Sklinna och kunde där konstatera en utomordentligt vacker glacialskulptur (fig. 2). Det är en glacial hälltopografi, vilken i mångt och mycket liknar den, som finnes i den bohuslänska granitskärgården.

Den mest frekventa glaciala strieringen finnes inom littoralzonen, varifrån den successivt avtager uppåt. På 4–5 meters höjd över medelvattenytan har erosionen i hällytan fortgått så långt, att isrefflorna helt utplånats, och granitytan nu ligger rå och ojämn.[1] Hällformerna äro dock fortfarande klart glaciala. Havets förmåga

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[1] Glaciala frakturer (Sichelbruch, Parabelriss) ha, på grund av att de ligga djupare i hällen, i allmänhet något större livslängd än isrefflingen.

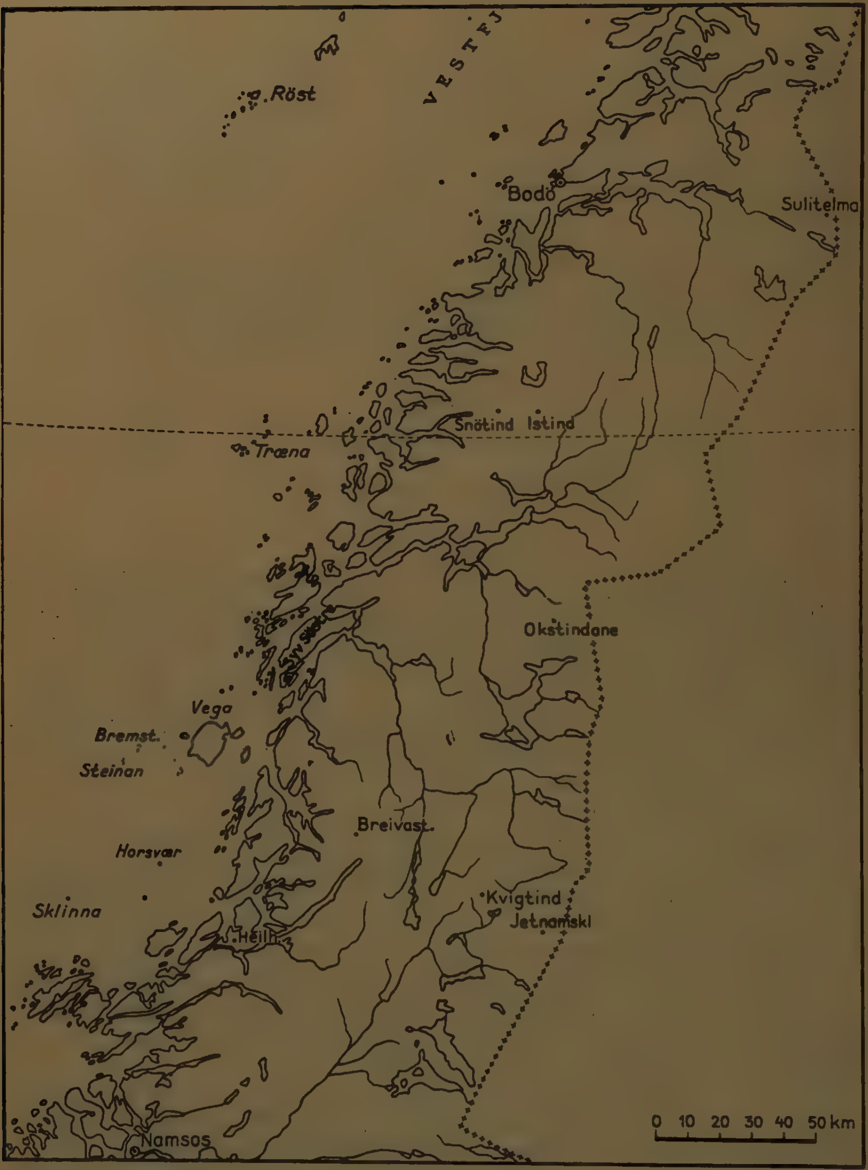

Fig. 1. Översiktskarta för Nordlands- och nordligste delen av Nordtröndelagskusten.

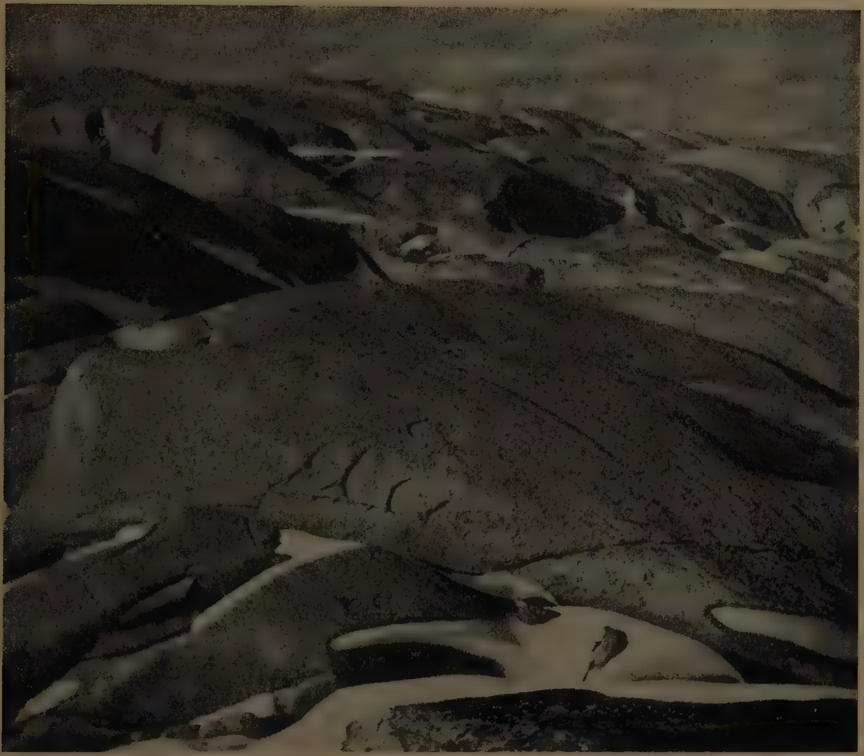

Fig. 2. Rundhällar med isrefling och Sichelbrüche på Heimöen, Sklinna.

att konservera glacial striering är sålunda klart exemplifierad på Sklinna. Först sedan hällarna genom landhöjningen passerat littoralzonen, utsättes isskuringen för effektivare utplåning.

Med de kunskaper man nu har om den glaciala hällutvecklingen, får hälltopografin på Sklinna anses ha bildats under ett istäcke av ansenlig mäktighet. Isrefflingen, vilken anger en rörelseriktning från S75E, torde ha inristats i hällarna av den senaste glaciationens ismassor. I slutskedet har en is av styvare beskaffenhet passerat ögruppen, vilket kan avgöras med hjälp av berggrundsfacetter, som isen ej förmått följa i botten utan ensidigt avjämnat.

Under senvintern 1957 kunde jag vid besök på platsen förvissa mig om att även Bremstein och Steinan, de yttersta skären väster om Vega (fig. 1), överskridits av ismassor från ESE.[1]

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[1] NORDHAGEN (1933) anför, i det han refererar till GRÖNLIE, att Vega varit isfritt.

Liksom Sklinna uppbygges Bremstein och Steinan av granit, i detta fallet en röd medelkornig till grovkornig mikroklingranit, vilken varit väl ägnad för glacial skulptur.

Av speciellt intresse beträffande iakttagelserna på Bremstein och Steinan är, att ismassorna med den observerade initialriktningen haft att passera den på sina ställen nu mer än 500 m djupa Vegafjorden.

Somrarna 1955 och 1956 fick jag tillfälle att besöka Træna, beläget ytterst på strandflaten just söder om polcirkeln (fig. 1). OXAAL (1915) och REKSTAD (1925), vilka i olika geologiska ärenden vistats på ögruppen, angiva samstämmigt, att isskuring saknas.

Berggrunden, vilken inom stora delar av Træna ligger helt blottad, består av en bandad gnejs[1], vars strykning är N60W och stupningen 35N. Den heterogena berggrundssammansättningen i förening med frekventa spricksystem bildar naturliga grundförutsättningar för en effektiv klimatisk vittring.[2]

Bland lösmaterialet på Trænas stränder påträffas allmänt block av erratisk karaktär. Belägna under högsta strandlinjen utgöra dylika dock inget bindande bevis för att ett område varit nedisat.

Utöver erratiska block (bl. a. Oslofältets porfyrbergarter och sparagmiter från den östra fjällranden) gav det första besöket på Træna vad beträffar glacialskulptur endast iakttagelsen av några rundhällsformade skär. Sistlidna sommar kunde emellertid på två hällar, belägna på öar strax öster om Husöen, iakttagas en parallell striering, vilken av allt att döma torde ha uppkommit genom isreffling (fig. 3). I båda fallen ligger den förmodade isskuringen på mot NNE stupande (c:a 40°) hällsidor, vilka nära överensstämma med gnejsens skiktstupning. På den större av hällarna finns en svag buktighet dock utan egentlig rundhällskaraktär. Strieringen har en ostsydostlig initialriktning snett uppåt på hällsidan. Till följd av hällytans lutning kan ingen exaktare riktningsangivelse för isrörelsen angivas.

På grund av hällytornas läge i förhållande till bergartens laminering får det ej bortses från den möjligheten, att tektoniska refflor kunna förekomma. Med hänsyn till i strieringen förefintliga karakteristika, såsom refflornas varierande uthållighet och bredd samt deras deviering med hällytans form, torde denna möjlighet kunna uteslutas[3] Ej heller kan det vara tal om reffling, åstadkommen av förbipasserande isberg med i botten infrusna block.

Förutom de ovan nämnda hällarna ha några andra, mindre säkra

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[1] Rekstad har i kartbladsbeskrivningen (REKSTAD 1925) i enlighet med äldre terminologi givit Trænas berggrund beteckningen granit, vilken genom pressning visar framträdande bankning. Jrf. fig. 2 i REKSTAD 1912.

[2] På Træna användes «granatgrus», utgörande vittringsprodukt från skikt av granatamfibolit, såsom vägbeläggning.

[3] Den på tektoniska glidplan ofta förekommande mineralutfällningen saknas.

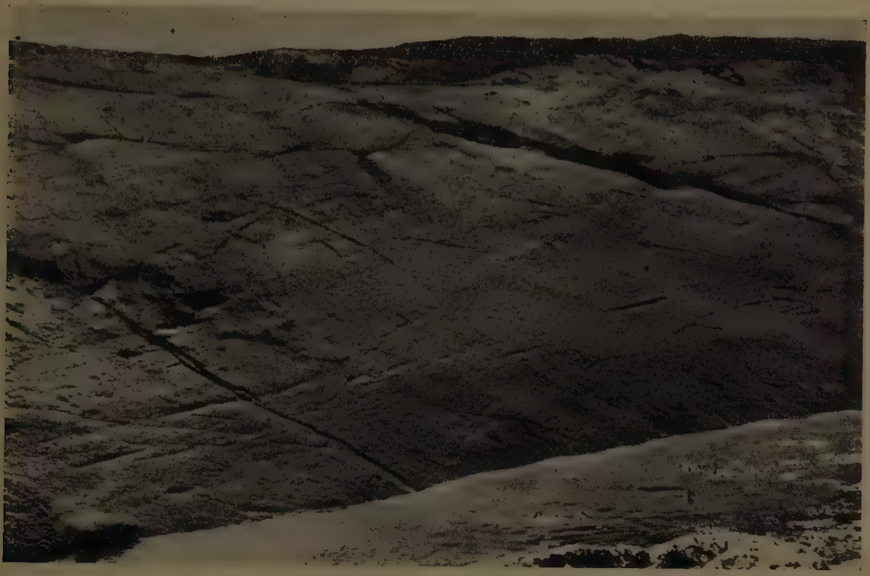

Fig. 3. Strierad häll på Torvöen, Træna.

lokaler med förmodad isslipning iakttagits, bl.a. vid Træna fyr i sydvästra delen av ögruppen. Den starka vittringen har där, såsom det förefaller, nästan utplånat refflorna på berggrundspartierna, vilka annars ha den glaciala hällformens kännetecken.

En faktor (vittringen har redan nämnts), som får tagas med vid bedömningen av den minimala förekomsten av glaciala erosionsspår på Træna, är berggrunden. Till skillnad från graniten på Sklinna och Bremstein är Trænas berggrund genom såväl sin heterogenitet som sina stupnings- och strykningsriktningar mindre ägnad för att inte säga direkt olämplig för utveckling och konservering av isskulptur, förorsakad av ismassor, framdragande från ESE eller SE, vilka riktningar av den glaciala strieringen på Solvær och Lovundvær att döma bör ha varit rådande inom den yttre delen av strandflaten i det aktuella området.

Ovan har nämnts (Sklinna) hurusom efter ytvittring på en glacial häll hällformen dock kan stå kvar. Detta förhållande kan med full klarhet konstateras över stora delar av den för vittringsprocesser starkt utsatta norska strandflaten. Frågan är nu, om man kan vända på denna empiriskt grundade sats. Kan en enligt glacialt mönster avrundad häll (utan möjlighet att tolkas såsom bankyta eller annan tektoniskt betingad yta, Wollsackvittring el. dyl.) belägen i en för vittring starkt utsatt kusttrakt, där bevarad isreffling saknas, tagas såsom bevis för glacial erosion och nedisning? Denna fråga ger en annan. Kan havets arbete prestera en liknande berggrundsyta som den, vilken bildas under ett rörligt istäcke? Blir svaret på den första frågan jakande, anser författaren, att en omprövning av slutsatser i refugiefrågan, vilka grunda sig på avsaknaden av isreffling, kan vara befogad.

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Gonnardite (Ranite) from Langesundsfjord

BY

BRIAN MASON

In 1874 Paijkull analysed a specimen from Langesundsfjord and described it as a new mineral. His description is as follows:

An der Insel Lamö bei Brewig in Norwegen kommt ein Mineral vor, das noch nicht bestimmt zu sein scheint. Es ist ein grauschwarzer Zeolith von feinkörniger Textur, der eine Metamorphose von Elaeolith sein muss, da er in dieses Mineral deutlich übergeht. Ich schlage für dieses Mineral den Namen Rauit vor, von Rau, der altnordischen Göttin des Meeres, weil das Mineral auf derselben Insel wie Azirin gefunden ist.

Die chemische Zusammensetzung ist:

SiO_2	39.21
Al_2O_3	31.79
Fe_2O_3	0.57
CaO	5.07
Na_2O	11.55
H_2O	11.71
	99.90

woraus die Formel $Al_2O_3 . SiO_2 + \frac{2}{3} Na_2O . SiO_2 + 2H_2O . \frac{1}{3} CaO$ hervorgeht. Der Rauit steht somit nahe dem Thomsonite.

Der Rauit ist völlig glanzlos; er enthält in kleiner Menge mehrere fremdartig Einschlüsse, wie Hornblende u. a., gleich wie es der Fall mit dem Elaeolith ist. Vor dem Löthrohre schmilzt der Rauit nur sehr schwierig und in dünnen Kanten. Sp. G bei 13° C = 2.48; H = 5. Der Rauit kommt nicht krystallisiert vor.

Lamö is the island now known as Låven; Rau is a misspelling for Ran, as Brögger (1890) pointed out, and the correct name of the mineral is ranite; azirin is a misspelling of aegirine.

Ranite has been generally accepted as a distinct species. Brögger considered it to be a sodium-rich thomsonite. Dana (1892, p. 609) classed it with hydronephelite, a poorly characterized mineral described by Clarke in 1886.

The American Museum of Natural History possesses a specimen (no. 13238) labelled «Ranite, Lamö, Norway», purchased from Dr. C. Hintze, Strasbourg, Alsace, in 1876. It agrees excellently with Paijkull's description. It consists of a dense dark gray mass about 8 cm × 8 cm × 2 cm, bordered on one side by white platy albite. From the date of purchase it seems probable that Hintze acquired the specimen either from Paijkull himself or from some other collector in Norway about the time of the original description.

An X-ray powder photograph of this dark gray material shows that it consists essentially of the rare zeolite gonnardite. Gonnardite was originally described from Chaux de Bergonne, France, by Gonnard in 1871, but identified as mesolite. Lacroix (1896) showed that it was a new mineral, and named it gonnardite. All the data on gonnardite are summarized in a recent paper by Meixner, Hey, and Moss (1956), who give the following additional localities for it: Capo di Bove, Rome, Italy; Weilberg, Germany; Aci Castello and Aci Trezza, Catania, Sicily; and Klöch, Styria, Austria. All these occurences are in cavities in basalt.

The X-ray photograph of ranite agrees with that given by Meixner, Hey, and Moss for gonnardite from Chaux de Bergonne. The examination of crushed grains of ranite by the immersion method shows that the material is fairly homogeneous, consisting of 95 % or more of grains with $\alpha' = 1.513$, $\gamma' = 1.515$. These indices are comparable with those of other specimens of gonnardite (Table 1), although a little higher. The grains are somewhat turbid with fine pigment, evidently the material which gives the dark gray color in the mass. Besides the gonnardite there are a small number of grains of a mineral with distinctly higher birefringence and $\alpha' = 1{,}480$, $\gamma' = 1.490$, probably natrolite.

Table 1. Chemical (atoms per unit cell) and optical data for ranite and gonnardite

	1.	2.	3.	4.	5.
Si	10.9	11.7	11.8	11.7	11.3
Al	10.4	9.1	9.0	8.8	8.6
Ca	1.5	1.2	1.0	2.3	2.7
Na	6.2	6.7	7.0	4.3	3.8
O	42.0	41.6	41.5	41.0	40.2
H_2O	10.9	10.8	10.7	12.2	13.0
(Si + Al)	21.3	20.8	20.8	20.5	19.9
(Ca + Na)	7.7	7.9	8.0	6.7	6.5
D	2.32	2.28	2.27	2.27	2.26
α'	1.513	1.498	1.497	1.506	1.506
γ'	1.515	1.502	1.499	1.508	1.508

1. Låven, Langesundsfjord
2. Klöch, Styria
3. Aci Trezza, Sicily
4. Aci Castello, Sicily
5. Chaux de Bergonne, France

The density of 2,48 given by Paijkull seemed rather high in comparison to the figures given for gonnardite, so the density of several grains of ranite was determined by suspension in acetonemethylene iodide mixtures. This determination gave a value of 2.32, in good agreement with that of gonnardite.

When Paijkull's analysis is calculated in terms of atoms per unit cell, following the procedure recommended by Hey (1939), the agreement in composition is clearly seen (Table 1).

The identity of ranite and gonnardite raises a difficult question of nomenclature. Paijkull's name clearly has priority, since it appeared more than twenty years before Lacroix described gonnardite. Usage, however, has relegated (incorrectly, as now appears) ranite to the category of rejected species, whereas gonnardite has been accepted as a well-defined mineral. Under these circumstances it seems unlikely that the name gonnardite can be replaced by ranite, however much priority might speak for this replacement. On the whole it seems best to accept gonnardite as the name for this zeolite, and add ranite to the synonymy.

The American Museum of Natural History
New York 24, N.Y.

July, 1957.

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The Crystal System and Space Group of Meta-Uranocircite.

BY

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Meta-uranocircite has been described as tetragonal or orthorhombic by different authors, although all agree that the mineral is optical biaxial. (NUFFIELD & MILNE 1953). An investigation of a sample of a mineral labelled meta-uranocircite from Wölsendorf, Bavaria, has been carried out by us. To identify the mineral with certainty optical measurements were carried out, and a powder x-ray diagram was taken. Single crystal x-ray diagrams show that the mineral is orthorhombic, presumably with the space group *Cmmm.*

The mineral is pale canary yellow in transmitted light, and faintly pleocroic. It shows twin lamellae in two directions at right angles, parallel to (100) and (010). The extinction positions of individuals were found to vary up to 5°—6° from the directions of the twinning planes. A very good biaxial interference figure was observed. 2E

Tab. 1. X-ray Powder Data for Meta-Uranocircite.

NUFFIELD & MILNE 1953.			ALVER & SELLEVOLL	
I.	dÅ.meas.	dÅ.calc.	I.	dÅ.meas.
7	8.19	8.44	M	8.60
6	5.37	5.37	M	5.44
3	4.90	4.92	W	4.98
6	4.21	4.22	M	4.18
10	3.58	3.61	VS	3.66
2	3.39	3.41	W	3.48
5	3.21	3.22	M	3.24
3	2.91	2.93	W	2.96
$^1/_2$	2.67	2.69		
4	2.59	2.61	M	2.60
$^1/_2$	2.41	2.42		
1	2.35	2.36	VM	2.37
		2.20		
2	2.18		W	2.20
		2.18		

Spacings below 2.18Å and intensities below 1.(VW) were not measured.
Ni filtered Cu-radiation: = 1.542Å.

Tab. 2. An example of the differences in intensities in the zones *hOl* and *Okl*. (The intensities of the two zones have not been put on the same scale).

hO1	$I_{obs.}$	Okl	$I_{obs.}$
401	34	041	27
402	29	042	43
403	16	043	9
404	3	044	7

was measured and found to vary within the ranges given by NUFFIELD & MILNE.

γ—α was measured with Bereck compensator, and found to be 0,004.

A powder diagram was taken with a Phillips camera (diameter 114 mm), using copper radiation (Cu$K\alpha, \lambda = 1{,}542$Å). The diagram was rather weak and diffuse, but eleven spacings could be measured with certainty. The results are up to 2 percent different from the data given by NUFFIELD & MILNE, and somewhat nearer to their calculated values than to their measured ones. The intensities seem identical (Tab. 1).

Single crystal oscillation diagrams and Weissenberg diagrams of the *hkO*, *hk1*, *hOl*, *Okl*, and *1kl* were taken, also with Cu-radiation. A crystal of (0.3 × 0.3 × 0.05) mm³ was used. The unit cell was found to have dimensions: $a = 13.9$Å, $b = 13.9$Å, $c = 16.9$Å. The measurements are supposed to be accurate within 0.5 percent. The axes *a* and *b* are in this case twice as long as reported by NUFFIELD & MILNE, while *c* is identical. All reflexions in the layers $h = 2n + 1$ and $k = 2n + 1$ are very weak, and would probably not have been detected if a small crystal had been used.

The intensities in the zones *hOl* and O*kl* did not seem identical by direct inspection of the films. Therefore the intensities within measuring range were estimated by the ordinary visual method. The spots were rather diffuse, and the results were not very accurate. There is, however, no doubt that the distribution of intensities in the two zones is distinctly different (Tab. 2). No evidence for deviations from the Laue symmetri *mmm* could be detected. It should therefore be safe to conclude that the crystals are orthorhombic (pseudotetragonal) in agreement with the optical properties.

No reflexions with $h + k = 2n + 1$ were observed. As no other systematical absences were found, the space group should be *Cmmm*.

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NUFFIELD, E. W. and MILNE, I. H.: Studies of radioactive Compounds: Meta-Uranocircite. Amer. Min. 1953.

Den XXI Internasjonale Geologkongress 1960.

Ved den XX internasjonale geologkongress i Mexico 1956 inviterte de nordiske land til neste kongress med møter i København og ekskursjoner i de nordiske land (Danmark, Finnland, Island, Norge, Sverige). Nasjonale komiteer ble oppnevnt i de nevnte land. Forslag til sammensetning av den norske komite ble fremlagt på NGF's generalforsamling febr. 1957 og av foreningens styre oversendt utenriksdepartementet. Komiteen ble oppnevnt i statsråd 29/3–57 og har følgende sammensetning:

Formann: Prof. O. Holtedahl,
Viseformann: Prof. T. F. W. Barth,
Sekretær: Konservator J. A. Dons.
Medlemmer:

Dir. E. Christophersen, varamann kontorsjef S. S. Nilson (Utenriksdept.), Dir. S. Føyn, varamann statsgeolog Chr. Oftedahl (N.G.U.), Prof. L. Störmer, varamann prof. T. Strand (Inst. f. Geol., Univ. i Oslo), Prof. N.-H. Kolderup, varamann prof. A. Kvale (Geol. Inst., Univ. i Bergen), Prof. Th. Vogt, varamann prof. J. Bugge (N.T.H., Trondheim), Dir. H. U. Sverdrup (†), varamann geolog T. Winsnes (Norsk Polarinstitutt), Dr. O. J. Adamson (Forsvaret), Prof. I. Th. Rosenqvist (Geotekn. Inst.), Dir. J. Kraft Johanssen (repr. for bergindustrien), Dr. H. Bjørlykke (A/S Norsk Bergverk), Dir. G. Randers (I. F. A.) Medlemmene har ikke arbeidsgodtgjørelse.

På det konstituerende komitemøte avholdt 8/4–57 ble retningslinjer for arbeidet og budsjettforslag behandlet. Det var da for året 1956/57 bevilget kr. 20 000, og ble senere for året 1957/58 bevilget kr. 50 000. Møter med representanter for de andre nordiske land er holdt i Göteborg 21/2 1957 der Barth og Dons møtte fra Norge, og i Stockholm 27/4 57 hvor Holtedahl, Barth og Dons møtte som den norske komites representanter. Et møte av sekretærene er avholdt i Oslo 7/9 57.

Det er planlagt et stort antall ekskursjoner i Norge. Lederne er i det vesentlige utpekt og meget forberedelsesarbeid er utført denne sommer. Det skal trykkes guide-books på engelsk for de enkelte ekskursjonene, videre er planlagt utgivelse av en «Norges geologi» på engelsk for hvilken O. Holtedahl er redaktør. Det arbeides nå særlig med planer for neste års feltarbeider samt oppstilling av seksjonene for møtet i København og valg av ledere for disse. Innbydelse til den XXI internasjonale geologkongress blir utsendt etter at det er avholdt et møte av representanter for de nasjonale komiteer i Finnland i forbindelse med Nordiske geologers vintermøte jan. 1958.

J. A. Dons.

NORSK GEOLOGISK FORENING

Generalforsamling torsdag 28. febr. 1957

i Drammensvn. 78, Oslo

Årsmelding for 1956

Siden siste generalforsamling er følgende medlemmer avgått ved døden:

Overingeniør Fredrik Carlson
Direktør N. E. Lenander

4 medlemmer er utmeldt av foreningen.

I samme tidsrom er innvalgt 16 nye medlemmer. Foreningen har nå 241 medlemmer, derav

2	korresponderende
111	livsvarige
128	årsbetalende.

Det er avholdt 5 ordinære møter med samlet frammøte av 176 personer.

Av Norsk Geologisk Tidsskrift er utkommet Bd. 36, h. 1—4.

Utdrag av regnskap for det ordinære budsjett for 1956.

Reuschmedaljen for 1956 ble tildelt cand. real. Bjørn G. Andersen for hans arbeide: «Randmorener i Sørvest-Norge. Norsk Geografisk Tidsskrift, bd. 14, h. 5—6, 1954, s. 273—342.

Utdrag av regnskap for det ordinære budsjett for 1956

Inntekt

Beholdning, overført fra 1955: I kasse ...	kr. 1 105,50		
I bank ...	» 3 047,49	kr.	4 152,99
Innbetalt medlemskontingent		»	1 515,00
Tilskudd fra Staten		»	1 200,00
Tilskudd fra Norges Almenvitenskapelige forskn. råd ..		»	7 569,00
Abonn. og salg av tidsskriftet.....................		»	2 350,48
Renter av bankinnskudd		»	93,85
Renter fra livsvarige medlemmers fond		»	771,69
Renter fra Berg- og Steinind. fond		»	600,09
		kr.	18 253,10

Utgift

Tidsskriftet:		
Trykking Bind 35, rest	kr.	2 379,90
Trykking Bind 36, h. 1 og 2	»	6 067,00
Klisjeer Bind 36, h. 1 og 2	»	1 502,00
Korrektur og tegnearbeide	»	743,40
Ekspedisjon av tidsskriftet	»	761,48
Arbeidshjelp, porto og skrivesaker	»	769,20
Møter og ekskursjoner	»	407,03
Representasjon, anskaffelse og Reuschmedaljen	»	68,20
Beholdning, overført til 1957: I kasse ... kr. 853,80		
I bank ... » 4 701,09	»	5 554,89
	kr.	18 253,10

Livsvarige medlemmers fond 1956

			Inntekt		Utgift
1/1 1956. Fondets kapital:					
Statsobligasjoner	kr. 11 500,00				
Aksjebrev	» 4 600,00				
Bankinnskudd	» 1 210,00				
Innbet. kont. i 1956	» 800,00				
Urørlig kapital	kr. 18 110,00				
Renter av verdipapirer		kr.	750,50		
Renter av bankinnskudd		»	52,10		
Forvaltning av verdipapirer				kr.	31,00
Overført til ordinært budsjett				»	771,69
		kr.	802,69	kr.	802,69

Berg- og steinindustriens gavefond:

			Inntekt		Utgift
Fondets kapital	kr. 20 000,00				
Renter for 1956		kr.	600,09		
Overført til ordinært budsjett				kr.	600,09
		kr.	600,09	kr.	600,09

Regnskapet revidert av T. Gjelsvik og T. S. Winsnes: 16/1 1957.

Valg:

Formann: *Nils Spjeldnæs.*
Viseformann: *T. Strand.*
Sekretær: *F. Hagemann.*
Redaktør: *N.-H. Kolderup.*
Styremedlemmer: *Chr. Oftedahl* og *Rosenlund* og formennene i Bergens og Trondheims geologiske klubber.
Reuschmedaljekomite: *H. Neumann*, *S. Skjeseth* og foreningens formann *N. Spjeldnæs.*

Revisorer: *T. Gjelsvik* og *T. Winsnes* med *G. Henningsmoen* og *T. Siggerud* som varamenn.

A. Granli ble anmodet om å fortsette sin virksomhet som forretningsfører.

Møte 365, torsdag 15. mars 1956.

Til stede 36 medlemmer og 15 gjester.

Foredrag av:

1. Statsgeolog *Chr. Oftedahl:*
   «Oslomagmaenes dannelse og *mise en place*».
2. Professor *Fridtjov Isachsen:*
   Geomorfologien i marxistisk belysning.

Referat av Jean Tricart: La géomorphologie et la pensée marxiste (Sbornik Ceskoslovenské Spolecnosti Zemespisné, 1952, p. 27-40), og noen kommentarer i tilknytning til referatet.

I ordskiftene etter foredragene deltok:

Kolderup, Dietrichson, Rosendahl, Holtedahl, Neumann, Strand, Spjeldnæs og foredragsholderne.

Møte 366, onsdag 9. mai 1956.

Til stede 25 medlemmer, 2 gjester.

Foredrag av professor *Harry von Eckermann:*

«En 6 km. lång profil gjenom Alnö-intrusionens conesheets, och nya iakttagelser över omvandlingar inom gångarna och angränsande berggrund».

I ordskiftet etter foredraget deltok: C. Bugge, O. Holtedahl, H. Bjørlykke, B. Dietrichson, H. Rosendahl og foredragsholderen.

Møte 367, torsdag 22. nov. 1956.

Til stede 19 medlemmer, 2 gjester.

Følgende innvalg ble godkjent:

405. Cand. mag. Christian Dick Thorkildsen, Blindern Studenterhjem, Oslo.
406. Stud. real. Gerald Muret, Studentforlegningen på Sogn.
407. Geolog Paul H. Reitan, Sørkedalsveien 229, Røa.
408. Dr. Walter C. Sweet, p. t. Geologisk Museum, Oslo.
409. Dr. G. T. Faust, U. S. Geological Survey, Washington 25, D. C., U. S. A.
410. Cand. mag. Knut Ørn Bryn, Nordbergveien 88, Oslo.
411. S. V. L. Rao, ass. lecturer in mineralogy, Indian institute of technology, Kharagpur, India, p. t. Geologisk Museum, Oslo.
412. Fil. kand. Ossi Näykki, Pihlajatie 43 A, Helsinki.
413. Fil. kand. Antti Savolahti, Jääkärinkatu 10 A, Helsinki.
414. Fil. kand. Erkki Viluksela, Outokumpu Oy, Outokumpu.

Foredrag av statsgeolog *Rolf W. Feyling-Hanssen:*
«Stratigrafi og skjærfasthet, noen mikropaleontologiske resultater»
I ordskiftet etter foredraget deltok:
Rosendahl, Rosenqvist, Bjerrum, P. Holmsen, Føyn, Strand, Spjeldnæs og foredragsholderen.

Møte 368 (julemøte) tirsdag 11. desember 1956, i Drammensveien 78, Oslo.

Til stede 62 personer.

Foredrag av statsgeolog *O. A. Broch:*
«Reise til Pakistan».

Møte nr. 369, torsdag 28. februar 1957.

Til stede 25 medlemmer — 10 gjester.
Følgende nye medlemmer ble opptatt i foreningen:
415. José M. Fuster, Museo Nacional de Ciencias Naturales, Madrid.
416. Geolog Finn Jørstad, Geoteknisk Institutt, Blindern.
417. Stipendiat, Landbrukskandidat Ola Einevoll, Norges Landbrukshøgskole, Vollebekk.

Foredrag av statsgeolog *Chr. Oftedahl:*
«En eksplosiv fase i Oslofeltets Permiske vulkanisme».
I ordskiftet etter foredraget deltok: T. Barth, J. Dons, H. Rosendahl, L. Størmer, T. Gjelsvik og foredragsholderen.

Møte nr. 370, torsdag 28. mars 1957.

Til stede 16 medlemmer — 4 gjester.

I forbindelse med referatet fra møte nr. 369 ytret P. Holmsen og E. Dahl seg.

Statsgeolog dr. Gunnar Holmsen ga en kort meddelelse om en langveis ført vandreblokk på Vest-Spitsbergen.

På toppen av Vesle Keglefjell, 806 m o. h., 8 km syd for Colesbukta, ligger i tertiærområdet mellom Isfjorden og Bellsund en blokk av grunnfjellsgranitt. Funnet av denne er gammelt og omtalt i Gunnar Holmsen: Beretning om en geologisk ekspedisjon til Spitsbergen 1909. — Bergens Mus. Årbok 1911 nr. 9, side 42.

Av Orvins geologiske oversiktskart fremgår, at blokken sannsynligvis stammer fra granittområdet øst for Wijdefjorden, og at en isstrøm herfra har ført den ut Billefjorden til dens nåværende leiested.

Et avslått stykke av vandreblokken ble vist frem på møtet. I det etterfølgende ordskiftet deltok O. Liestøl og G. Holmsen.

Foredrag av lektor *Isak Undås:*
«Om Ra-morenen og Svelvikstadiet i Ryfylke og Sunnhordland».
I ordskiftet etter foredraget deltok: B. Andersen, K. Strøm, G. Holmsen og foredragsholderen.

Årsmelding for 1956
fra Bergens geologiske klubb.

Møte nr. 56, 5. mars.
Foredrag av professor dr. *Niels-Henr. Kolderup:* «Betraktninger over Sunnhordlandsbatolitten». 15 tilhørere.

Møte nr. 57, 12. mars.
Foredrag av cand. real. *Markvard A. Sellevoll:* «En undersøkelse av jordskjelvene i Vestnorge 7. og 10. juli 1954». 18 tilhørere.

Møte nr. 58, 20. april.
Foredrag av amanuensis *Ivar Hernes:* «Surnadalsynklinalen og det VSL-lige foldesystem i midt-Norge». 12 tilhørere.

Møte nr. 59, 11. mai.
Foredrag av cand. real. *Trygve Nesse:* «Mikroseismisk uro ved jordskjelvstasjonen i Bergen». 9 tilhørere.

Møte nr. 60, 8. oktober.
Foredrag av professor dr. *Ivan Th. Rosenqvist:* «Våre leirers mekaniske egenskaper». 20 tilhørere.

Møte nr. 61, 15. desember. Julemøte.
Foredrag av amanuensis *Ivar Hernes:* «Italienske streiftog». Med fargelysbilder. 29 tilhørere. Etter foredraget selskapelig samvær på Geologisk institutt.

Styret var i 1956: Formann: dosent Anders Kvale, viseformann: lektor A. Samuelsen, sekretær: amanuensis Ivar Hernæs.

GEOLOGNYTT

Norges geologiske undersøkelse.

Cand. real. **Fredrik Hagemann** ansatt som statsgeolog pr. 1. mars 1957.

Dr. philos. **Frank M. Vokes** sluttet som midlertidig statsgeolog pr. 31. mars 1957.

Licensié **Tony Van Autenboer** sluttet som midlertidig vitensk. assistent pr. 9. april 1957.

Dwight F. Crowder, M. Sc., ansatt midlertidig som statsgeolog pr. 15. juni 1957.

Cand. mag. **Harald Skålvoll** ansatt midlertidig som vitensk. assistent pr. 1. juli 1957.

Stud. real **Lisbeth Reh** ansatt midlertidig som vitensk. assistent i halv post pr. 1. oktober 1957.

Statsgeolog **Per Holmsen** har fått tjenestefrihet fra sin stilling ved NGU i ett år fra 1. oktober 1957.

Universitetet i Oslo.

Professor dr. **Olaf Holtedahl** er utnevnt til Honorary Member of the Royal Society of Edinburgh.

Mineralogisk-geologisk museum.

Alf Granli, tidligere preparant ved museet i over 40 år, er fra 1. januar 1957 ansatt som konservator.

Assistent, cand. real. **Knut Heier** har fortsatt permisjon fra sin stilling til studier ved Oxford University i England.

Cand. mag. **Thor Sverdrup** fungerer fortsatt som vikar under Heiers permisjon.

Cand. mag. **Knut Ørn Bryn** er ansatt som museumsstipendidat for året 1957/58.

Cand mag. **Olav H. J. Christie** er ansatt som assistent ved røntgenlaboratoriet fra 1. juli 1957.

Stud. real. **Viggo Wiik** er ansatt som laborant ved røntgenlaboratoriet fra 1. september 1957.

Følgende gjestende forskere arbeider ved museet i året 1957/58:

Statsstipendiat B. A. O. RANDALL, B. Sc., F.G.S., University of Durham, Newcastle-on-Tyne, England.

Statsstipendiat W. A. ELDERS, B. Sc., University of Durham, Newcastle-on-Tyne, England.

Fulbrightstipendiat H. H. SCHMITT, B. Sc., California Institute of Technology, Pasadena, Calif., U.S.A.

Fulbrightstipendiat A. B. PARKER, B. A., Harpur College, Endicott, N.Y., U.S.A.

Paleontologisk museum.

Konservator I GUNNAR HENNINGSMOEN ble 11. juni 1956 ansatt som førstekonservator samme sted.

HENNINGSMOEN ble av Det akademiske kollegium kreert til doctor philosophiæ i juni 1957 etter å ha forsvart sin avhandling: «The Trilobite Family Olenidae. With description of Norwegian material and remarks on the Olenid and Tremadocian series.»

HENNINGSMOEN har fått et års permisjon fra sin stilling fra 1. oktober 1957, for å foreta en studiereise i U.S.A., med stipendium fra Norges Almenvitenskapelige Forskningsråd.

Cand. real. SVEIN MANUM er ansatt som vikar for Henningsmoen under dennes permisjon.

Paleontologisk institutt

er i november 1957 flyttet inn i nybygget for de geologiske institutter på Blindern.

Eksamener.

OTTAR JØSANG har i høstsemestret 1957 fullført magistergraden i mineralogi-petrografi. Avhandlingens titel: «Beskrivelse av bergartene i området mellom Haugsfoss og Kløftefoss i Modumfeltet med forsøk på tolkning av noen metasomatiske prosesser som disse bergartene har gjennomgått.»

Norges Statsbaner.

Statsgeolog PER HOLMSEN er fra 1. oktober 1957 blitt ansatt som geolog ved Norges Statsbaner, Hovedstyret, Oslo.

Universitetet i Bergen.

Geologisk institutt.

Dr. ANDERS KVALE ble i statsråd 21. juni utnevnt til professor i geologi, med særlig plikt til å bestyre jordskjelvstasjonen.

Førstekonservator HANS HOLTEDAHL er av Det akademiske kollegium kreert til doctor philosophiæ 8. november 1957, etter å ha forsvart sin avhandling: «On the Norwegian Continental Terrace, primarily outside Møre — Romsdal: its Geomorphology and Sediments.»

Jordskjelvstasjonen.

Norges Almenvitenskapelige Forskningsråd har i juni 1957 bevilget midler til opprettelse av en jordskjelvstasjon på Spitsbergen. Den vil bli utstyrt med en Willmore seismograf. Stasjonen vil først kunne opprettes sommeren 1958, og der er ikke tatt endelig bestemmelse om den skal ligge i Longyearbyen eller ved Isfjord radio.

Cand. real. MARKVARD A. SELLEVOLD er ansatt som vitenskapelig medarbeider ved stasjonen.

Norges tekniske høgskole.

Geologisk institutt.

Magister OTTAR JØSANG har tiltrådt som vitenskapelig assistent.

MEDLEMSLISTE

à jour oktober 1957.
¹: korresponderende medlem.
*: livsvarig medlem.
Tallet i parentes er innvalgsåret.
(S), stifter (18. februar 1905).

*Adamson, Olge J., dr. Postboks 42, Smedstad pr. Oslo (1945).
Ahlmann, Hans W:son, professor, Fregattvägen 6, Gräsdal, Stockholm S.V., Sverige (1919).
Andersen, Bjørn, univ.stip. Geologisk institutt, Blindern, Oslo (1952).
Asklund, Bror, statsgeolog, Sveriges Geologiska Undersökning, Stockholm 50. (1938).
*Bache, Laura, lektor. Eiksbo, vei 509, Eiksmarka, Røa, Oslo (1931).
*Backlund, Helge, professor. Mineralogisk-geologiska Institutionen, Uppsala 1. (1919).
Baker, Donald, B.Sc. The Ohio Oil Company, P. O. Box 269, Littleton, Col., U.S.A. (1951).
Bakken, Asbjørn, lektor. Voss Landsgymnas, Voss. (1954).
*Barth, Tom, F. W., professor. Geologisk museum, Oslo 45. (1921).
Bergersen, Birger, statsråd. Anton Schjøthsgt. 13, Oslo. (1921).
Bertheau-Hansen, Chr., bergingeniør. Norges geologiske undersøkelse, Oslo 27. (1942).
Birkeland, Tor, lektor. Avaldsnesgt. 36, Stavanger. (1946).
Bjerrum, Lauritz, direktør. Norges geotekniske institutt, Blindern, Oslo. (1952).
*Bjørlykke, Harald, dr. Norsk Bergverk, Christian August's gate 15, Oslo. (1923).
Boughton, Eric. Hay Tor, 921 Harrow Rd., Wembley, Middlesex, England. (1932).
*Broch, Olaf Anton, statsgeolog. Norges geologiske undersøkelse, Oslo 27. (1920).
Bruun, B., ingeniør. N.G.U. Geologisk museum, Oslo 45. (1938).
Bryhni, Inge, cand.mag. Geologisk institutt, Universitetet i Bergen. (1955).
*Bryn, Knut Ørn, cand.mag. Borgenvn. 39, Vindern, Oslo. (1956).
Brøndbo, Knut, bergingeniør. A/S Titania, Hauge i Dalane. (1955).
*Braastad, Johan, dr. Postboks 808, Oslo. (1913).
Bugge, Arne, dr. Utsiktsveien 21, Stabekk. (1914).
*Bugge, Carl, direktør, Håkon den gode's vei 12, Vindern, Oslo. (S).

*Bugge, Jens, professor, Norges tekniske høgskole, Trondheim. (1940).
*Bulman, O. M. B., Sedgwick Museum, Cambridge, England. (1951).
*Callisen, Karen, dr. Mineralogisk og Geologisk Museum, Østervoldgade 7. København K. (1917).
Cameron, Richard. Dept. of Geology, Ohio State Univ., Columbus 10, Ohio, U.S.A. (1956).
*Carstens, Harald, geolog. Saxenborg, Trondheim. (1949).
Caster, Kenneth, professor. Dept. of Geology and Geography, University of Cincinnati, Cincinnati, Ohio, U.S.A. (1953).
*Chapman, Charleton, A., professor. University of Illinois, Urbana, Ill., U.S.A, (1949).
*Chen Kwan Yuan, B. Sc. Geological Institute, National Peking University, Peking, Kina. (1951).
Collini, Bengt, fil.lic., laborator. Kungl. Lantbrukshögskolan, Institutionen för Marklära, Uppsala 7, Sverige. (1949).
Craig. H. B., dr. Dept. of Geology, University, Chicago 37, Ill., U.S.A. (1949).
*Dahl, Eilif, cand. real. Botanisk institutt, Norges Landbrukshøgskole, Vollebekk. (1946).
Dahl, Erling, ingeniør. Skogveien 1, Notodden. (1945).
Dahlström, Elis, dr. Lundberg Explorations Ltd. AB, Lindhagensgatan 132. Stockholm K., Sverige. (1945).
Danielsen, Anders, konservator. Botanisk museum, Bergen. (1949).
*Devore, George W., dr. Dept. of Geology, University, Chicago 37, Ill., U.S.A. (1948).
Dietrichson, Brynjulf, bergingeniør. Norges geologiske undersøkelse, Oslo 27. (1917).
Donnay, J. D. H., professor. Johns Hopkins University, Baltimore 18, Maryland, U.S.A. (1937).
*Dons, Johannes A., konservator. Geologisk museum, Oslo 45. (1941).
*Eckermann, Harry von, professor. Edeby pr. Ripsa, Sverige. (1937).
*Edelman, Nils, dr. Torggatan 33, Mariehamn, Finnland. (1956).
Egeberg, F. P., bergingeniør. Rådhusgata 5b, Oslo (1939).
Einevoll, Ola, landbrukskandidat. Norges Landbrukshøgskole, Vollebekk. (1957).
Elliott, Robert B., dr. Department of Geology, The University, Nottingham, England (1954).
Enkovaara, Antti, magister. Oulainen, Finnland. (1947).
Eriksen, Edv. Andreas, bergingeniør. Uranienborgveien 11c, Oslo. (1945).
*Eskola, Pentti, professor, Min.-geol. Inst., Universitetet, Helsingfors. (1919).
Espeland, Margaret, B. Sc. Hus 2, Vei 3672, Nordstrandhøgda, Oslo (1950).
*Falkenberg, Otto, ingeniør. Priorveien 7, Smestad, Oslo. (1914).
Faust, G. T., dr. U.S. Geological Survey, Washington 25 D. C. U.S.A.
Feyling-Hanssen, Rolf, statsgeolog. N.G.U. (1950).
*Fuster, José M., professor. Museo National de Sciencias Naturales, Madrid, Spania. (1957).

*Fægri, Knut, professor. Botanisk museum, Bergen. (1935).
Færden, Johannes, geolog. A/S Norsk Bergverk, Chr. Augustgt. 15, Oslo. (1948).
*Føyn, Sven, direktør. Norges geologiske undersøkelse, Oslo 27. (1932).
Garthus, Torbjørn, lærar. Garthus, Valdres. (1943).
Gavelin, Sven, professor. Mineralogiska Institutet, Stockholms Högskola, Stockholm, Sverige. (1954).
Gillberg, Gunnar, fil. lic. Stockholms Högskola, Stockholm, Sverige. (1952).
*Gjelsvik, Tore, statsgeolog. Evjebakken 18, Sandvika. (1945).
Gjessing, Just, amanuensis. Geografisk institutt, Blindern, Oslo. (1953).
*Gleditsch, Chr., geolog. Bentsegt. 10, Oslo, (1941).
*Green, John, C., B. A. 183 North Main Street, West Hartford, Conn., U.S.A. (1954).
Grenness, Johannes, ingeniør. Statens råstofflaboratorium, Østmarka, Trondheim. (1945).
*Grip, Erland, fil. lic. Boliden, Sverige. (1938).
*Grønlie, Arne, rektor. Mo komm. høgre almenskole, Mo i Rana. (1943).
Hafsten, Ulf, dr. Botanisk Museum, Bergen. (1957).
*Hagemann, Fredrik, statsgeolog. Norges geologiske undersøkelse, Oslo 27. (1951).
*Hagner, A. F., professor. Dept. of Geology, University of Illinois, Urbana, Ill., U.S.A. (1947).
Hansen, Kaj, dr. Gammeltoftsgade 16, København K. (1947).
*Harry, W. T., B. Sc. Department of Geology, The University, St. Andrews, Fife, Scotland. (1949).
*Hartley, Jack, B. Sc. Department of Geology, University, Leeds 2, England. (1949).
*Hawkes, Leonard, professor, D. Sc., F.R.S. 26 Moore Lane, Rickmansworth, Herts., England. (1915).
*Heber, Gustav, advokat. Oscarsgt. 49. Oslo (1937).
*Heber, Gustav, bygningsingeniør. Oscarsgt. 46b, Oslo. (1942).
*Heier, K. S., cand. real. Geologisk museum, Oslo 45. (1952).
*Heintz, Anatol, professor. Geologisk museum, Oslo 45. (1926).
*Heintz, Natascha, cand. real. Homans vei 24, Blommenholm. (1951).
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2	korresponderende medlemmer.
118	livsvarige medlemmer.
123	årsbetalende medlemmer.
243	medlemmer.